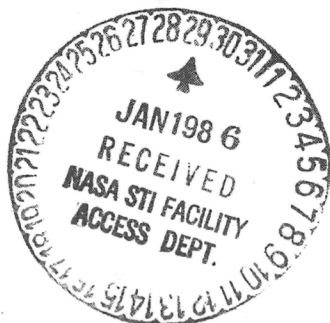


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# ASSESSMENT OF U.S. INDUSTRY'S TECHNOLOGY TRENDS AND NEW TECHNOLOGY REQUIREMENTS



CONTRACT NASW - 3674

## TASK 6 - FINAL REPORT

PREPARED FOR:  
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
TECHNOLOGY UTILIZATION AND INDUSTRY AFFAIRS DIVISION  
WASHINGTON, D.C. 20546

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CROFTON, MARYLAND 21114

OCTOBER 1984

ASSESSMENT OF U.S. INDUSTRY'S  
TECHNOLOGY TRENDS AND  
NEW TECHNOLOGY REQUIREMENTS

TASK 6 - FINAL REPORT

CONTRACT NASW-3674

"USER REQUIREMENTS FOR  
THE COMMERCIALIZATION OF SPACE"

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## EXECUTIVE SUMMARY

The objective of Task 6 was to **test** the utility and effectiveness of a novel approach (the Applications Development, or AD approach), intended to augment the efficiency of NASA's technology utilization (TU) through dissemination of NASA technologies and joint technology development efforts with U.S. industry. The **innovative AD approach** consists of the following key elements:

- Selection of NASA technologies appearing to have "leading edge" attributes.
- Interaction with NASA researchers to assess the characteristics and quality of each selected technology.
- Identification of industry's needs in the selected technology areas.
- Structuring the selected technologies in terms of specifications and standards familiar to industry (Industrial Spec. Sheets).
- Identification and assessment of industry's interest in the specific selected NASA technologies, utilizing the greatly facilitated communication made possible by the availability of the Industrial Spec. Sheets.
- Matching selected NASA technologies with the needs of selected industries.

The matching approach resulted in the identification of the following six areas of expressed industry interest in NASA technology research and developments.

### NASA RESEARCH AREA

Materials/Composites

Automation Technology/  
Robotics/Teleoperators

### INDUSTRY INTEREST

High strength to weight  
structures

Remote control of hazardous  
processes

Power Conversion & Distribution

High power electrical  
switching

Non-Destructive Evaluation (NDE)

High resolution micro-  
structure evaluation

Tribology (Surface Science)

Applications of surface  
science to controlling  
mechanical wear and friction

Photovoltaic Energy Conversion

Generation of electric energy  
from solar energy

The ~~conclusions~~ resulting from the conduct of Task 6 are:

- The innovative Applications Development (AD) approach enhances the probability of earlier and smoother transfer of high-leverage/leading-edge technology from NASA to industry.
- The three elements which are key to implementing the AD approach are: 1) in-depth knowledge of industry and of industrial needs and concerns; 2) extensive in-depth knowledge of industrial technologies; and 3) familiarity with advanced and emerging NASA technologies.
- Industry understanding of, and interest in, NASA technology is greatly increased by structuring NASA's published research information into specifications and standards commonly used, accepted, and understood by U.S. industry; e.g., ASME, ASHRAE, SAE, ASTM, IEEE.
- The AD approach should reduce by several years the length of time normally required to effect technology transfers from NASA to industry.
- The AD approach tested would complement NASA's current TU role. It would not replace the established TU organization and mechanisms.

- The data and information produced by the tested approach could serve to profitably fine-tune NASA's RTOPs to increase their industrial orientation, without unduly affecting NASA's primary research mission.
- To implement this AD approach successfully, NASA must utilize its best expertise and in-depth experience in relating the value perceptions of industry to the outlook of NASA's researchers.

The **principal recommendations** resulting from the conduct of Task 6 are:

- NASA and industry would benefit significantly from implementing the innovative AD approach developed by NASA's TU Office and ECOsystems.
- An important element of the implementation would be to supplement the current TU "Tech Briefs System". This should be accomplished by communicating selected technologies in terms of specifications and standards that are easily understood and commonly accepted by industry.

**Additional recommendations** resulting from observations during this effort are:

- Consider providing TU activities at Field Centers with appropriate budgetary means to better accomplish the TU mission. An important need is a budget to which Center researchers can charge time spent in interfacing with industries.
- Consider establishing a procedure whereby NASA's TU Office can fine-tune RTOPs in order to enhance the industrial orientation and eventual commercial application of the research.

## FOREWORD

This report was compiled in fulfillment of Task 6 of Contract NASW-3674 entitled "User Requirements for the Commercialization of Space." It was prepared by ECOsystems International, Inc. for the National Aeronautics and Space Administration Headquarters, Directorate, Technology Utilization and Industry Affairs.

The purpose of Task 6 was to develop and test an innovative method and approach, hereinafter referred to as the Applications Development (AD) approach, to enhance NASA's technology utilization process. The approach was developed by ECOsystems upon suggestion by the Directorate, Technology Utilization and Industry Affairs Division, NASA Headquarters.

The essence of the new method and approach lies in four ingredients:

- **Identifying** and **characterizing** NASA technologies having possible industrial application, **early** in their research stage.
- **Formulating** the technologies' characteristics into **specifications** and standards readily **understood** and **used** by industry.
- **Identifying** industry **users** having perceived **requirements** for the technologies.
- **Assessing** these **user's interest** in the specific NASA technologies investigated.

## CHAPTER I

### CONCEPT OF TECHNOLOGY UTILIZATION (TU) EFFECTIVENESS ENHANCEMENT

NASA's classical TU role has been to identify, sort, disseminate, and ultimately transfer specific technologies developed for space and/or aeronautical programs to U.S. industry. In recent years, this role has broadened and gained urgency, particularly as a result of recent initiatives by the President. TU's role includes cooperative technology developments with interested industrial R&D organizations. In these, NASA contributes research funding and high technology know-how. In return, industry provides a level of funding and applied technology, as well as commercial marketing expertise and applications know-how not readily available within NASA. Significant benefits have accrued to industry, and to the general public, as a result of the TU program developed and fostered by NASA.

Previous studies have evaluated the effect of the TU program with industry as being highly successful. NASA's proven track record ensures that further benefits will be obtained by applying TU resources optimally to "high-leverage" technology transfer opportunities to industry. "High-leverage" means NASA technologies and know-how having high potential for benefiting industry and the nation.

Through innovative management design, the TU program has undergone constant evolution over the years. The approach reported herein, developed by the TU Headquarters Office and ECOsystems, is one more step in TU's evolution. The proposed effort is oriented toward near-term results, i.e., technologies likely to reach industrial commercial payoff within 2 to 4 years.

The current TU mechanism relies to a large extent upon the "**Tech Briefs System**". This system typically operates in accordance with the following sequence of events, see Appendix A for details:

- The **Innovator** (NASA scientist or NASA contractor)
  - Generates novel idea or concept
  - Engages in theoretical and experimental research and laboratory test work



- Publishes findings in Technical Papers, Reports, Technical Presentations
- Periodically produces documentation for project justification and other specialized purposes, such as RTOP submittals, Patent Applications
- The **Technology Utilization Officer** (TUO) becomes aware of the research effort and develops contact with the innovator. The TUO initiates action to publish information in quarterly **Tech Briefs** through the following procedure:
  - Review of the innovative idea and/or concept for commercial applicability
  - Preparation of one page summary characterizing the innovation
  - Submittal for review, concurrence, publication approval
  - Printing and publishing of approved summary
  - Distribution of information relative to the innovation through NASA publication media, including **Tech Briefs** journal

The TUO's contacted indicate that, on the average, from the earliest availability of promising experimental work to the publication in the **Tech Briefs**, the above procedure involves a time span of the order of two to three years.

In contrast, the AD approach to technology transfer, tested in this Task, would only require that the following direct actions take place through a "technology applications specialist". He deliberately seeks out the NASA **innovator at the earliest practicable phase** of his experimental work and proceeds as follows:

- In concert with the innovator, engages in **characterizing** the inovator's research and the expectation which the research portends for industry.

- Assesses the industrial **application** potential of the research.
- Casts or translates the innovator's scientific information into **specifications** suitable for comprehension by industry.
- **Tests** and **verifies** the value of the innovator's technology with appropriate industry sources.

The information gathered from the innovator could be used, as desired, to fine tune the innovator's experimental work through his RTOP. This could influence the innovator's RTOP toward earlier fruition of practical industrial/commercial applications.

When we initiated the investigation, it was thought that the AD approach could reduce the lag in transfer from NASA to industry of selected "leading-edge" technologies by perhaps one to two years. The results obtained during the conduct of this task verified this assumption: in fact, they indicate that two years may be a conservative underestimate.

## CHAPTER II

### METHODOLOGY AND FINDINGS

The method employed to implement and test the effectiveness of the Applications Development (AD) approach encompassed the elements indicated following.

#### **Selection of Research and Technology Areas**

Our initial step was to identify the NASA projects involving "leading edge" technologies, and cognizant researchers conducting them. This was accomplished by carefully reviewing the FY '84 issue of the RTOPs Summary (NASA TM-85415). Integrated with analysis of ECOSystems industrial files, this review identified RTOPs which appeared to pursue "leading edge" technology opportunities in high-leverage areas of interest to industry. Thirteen RTOPs were selected, as indicated in Table 1.

#### **Characterization of Selected Technology Areas**

The next step was to contact the responsible technical monitors of the selected RTOPs. Using a specially developed questionnaire, the researchers were asked to provide details about their programs. The results of these initial informal queries are shown in the completed questionnaires contained in Appendix B, an example of which is presented in Figure 1. Analysis of the responses, coupled with our knowledge of industry needs, allowed us to validate the quality of the thirteen RTOPs initially selected for investigation. Although each of the RTOPs had well-defined and unique space-oriented objectives, there turned out to be overlaps among them as regards their applicability to industrial technology. We therefore combined several of the selected RTOPs, and set up visits to the monitors of those indicated by the designation "yes" in the last column of Table 1.

Visits were made to the Langley and Lewis Research Centers to discuss the selected RTOP projects with the researchers involved. Extensive technical discussions were held with the technical monitors and their associate researchers.

Supplemental contacts were made with other NASA investigators to obtain additional information, as necessary.

TABLE 1  
SELECTED RTOPS OF INTEREST

<u>CURRENT RTOP NUMBER</u>	<u>RTOP ACCESSION NUMBER</u>	<u>SUBJECT</u>	<u>FILE NO. ON QUESTIONNAIRE</u>	<u>PRINCIPAL TECHNICAL MONITOR</u>	<u>CENTER</u>	<u>VISIT</u>
505-33-33	W84-70026	Composites	1.	Vosteen	LRC	Yes
534-06-23	W84-70135	Composites	2.	Vosteen	LRC	Yes
506-53-12	W84-70145	Materials	3.	Lowell	LeRC	Yes
506-54-61	W84-70182	Expert Systems	4.	Lum	ARC	No
506-54-63	W84-70183	Automation Technology	5.	Meintel	LRC	Yes
506-57-23	W84-70220	Remote Manned Control	5a.	Meintel	LRC	Yes
506-54-66	W84-70185	Machine Intelligence	6.	Friedman	GSFC	No
506-55-42	W84-70191	Photovoltaic Energy	7.	Brandhorst	LeRC	Yes
506-55-48	W84-70194	Solar Power Analysis	8.	Carruth	MSFC	No
506-55-52	W84-70196	Electrochemical Energy Storage	9.	Thaller	LeRC	Yes
506-55-55	W84-70198	Advanced Batteries	10.	Stein	JPL	No
506-55-73	W84-70204	Advanced Space Power	11.	Conway	LRC	Yes
506-55-76	W84-70206	Advanced Space Power	12.	Ford	GSFC	No

## QUESTIONNAIRE FOR RTOP PRINCIPALS

NAME: R.C. Goetz (talked to Louis Vosteen)

ADDRESS: LARC

TEL. NO.: 804-865-2042

CENTER/DEPARTMENT:

RTOP NUMBER: W84-70135 (534-06-23)

RTOP TITLE: Composite Materials and Structures

RTOP FUNDING: 2 1/2 Million

ESTIMATED PROGRAM DURATION: 5 Years

WHEN DID PROGRAM START: FY 1982

NUMBER OF NASA PERSONNEL INVOLVED: 25

ARE CONTRACTORS INVOLVED (INDUSTRIAL AND/OR ACADEMIC):

Many of both.

OTHER NASA CENTERS INVOLVED: LERC - AMES - JPL

WHAT ARE OBJECTIVES OF THE PROGRAM:

Improve the toughness of composite materials such as fatigue, fracture, etc. Also develop processing technology for advanced composite matrix resins and material forms. Improve performance.

WHAT ARE KEY PARAMETERS THIS RTOP IS AIMED AT IMPROVING:

Strain to failure with induced damage and fracture behavior of composites

WHAT NASA SPACE OR AERONAUTICS PROGRAM IS RTOP AIMED AT:

Application of composites to transport aircraft coupled with energy conservation projects.

IS THIS RTOP BASIC RESEARCH OR DEVELOPMENT:

More oriented toward advanced development.

DO YOU SEE AN INDUSTRIAL APPLICATION FOR THE PROGRAM RESULTS:

Yes - any polymeric system using composite materials (resin matrix)

WHERE DO YOU THINK YOU ARE WITH RESPECT TO INDUSTRY DEVELOPMENTS:

Ahead in understanding, even or behind in applications.

WHAT INDUSTRIES ARE WORKING IN THIS SAME AREA:

Any industry using materials.

ARE THESE INDUSTRIES AHEAD OR BEHIND IN RESPECT TO WHERE YOU STAND:

Comparable.

WHAT IS RTOP SCHEDULE FOR GENERATION OF RESULTS (IN TERMS OF SIGNIFICANT ACCOMPLISHMENTS/MILESTONES AND WHEN):

Target for a material strain to failure (.004). In 1988 hope for ultimate strain of .006 which is a 50% improvement in compression

ANY OTHER INFORMATION YOU MAY WISH TO VOLUNTEER:

In addition to verbal information, technical documentation was supplied to ECOsystems by the NASA researchers contacted. See Appendix C and Appendix D for detailed Trip Reports concerning these visits.

In addition to the extensive amount of technical information gathered during the investigative trips, valuable ancillary technical documentation and information was obtained from the Technology Utilization Officers.

A listing of technology opportunities found during our visits and their specific characterizations is provided in Appendix E. An example is the experimental work in carbon fiber structural materials being pursued at Langley Research Center (LaRC). Pertinent descriptions and characteristics obtained from discussions with NASA researchers are exemplified by the following:

GENERIC TECHNOLOGY:  
Materials/Composites

SPECIFIC TECHNOLOGY:  
Carbon Fiber Structures

- LaRC uses primarily graphite fibers in diverse configurations: chopped fiber blocks, continuous rods, filament-wound shapes, and laminated sheet "layups".
- The composites have great unidirectional strength. The strength is however not equal in all directions. This requires careful design; there is need to compromise strength, weight, and other properties to achieve design requirements. Current strength is equal to or superior to the best available for light-weight metals.
- In particular, the strength-to-weight ratio is higher than for Aluminum.
- The density of the composite material is 65% that of Aluminum.
- Cost is up to \$50 per lb. for the raw material; \$100-\$150 per lb. for in-place material in aerospace structures.
- The fiber technology can produce the complex shapes needed by the aerospace industry.

- Composites are more difficult to machine than metals. Machining requires special drills, saws, etc.
- Currently used resins exhibit only 15-20K psi tensile strength along the non-fiber-reinforced axis. There is a need for "tougher" resins.
- The diameter of the individual fiber used is approximately 6 microns. Fibers are supplied by the manufacturers packaged in "tows" of 3,000, 6,000 or more fibers.
- The currently small production implies high cost. The total U.S. production of carbon fibers is approximately three million pounds per year. (For Kevlar fibers, approximately ten times as much is produced.)
- Thermoplastics are being tried in substitution for resins, but they are sensitive to corrosion.

### **Initial Fit of Technologies Within Industrial Sectors**

The next step was to evaluate technological needs of industry sectors, germane to the NASA technologies being investigated. By industrial sectors are here meant groups of industrial establishments specializing in particular products or services, as per the Standard Industrial Classification (SIC). Our evaluation was based upon specific past studies, industrial statistical data, and the massive data base on "industry profiles" assembled, analyzed, and synthesized by ECOsystems under NASA Contract NASW-3864.

Among the data sources assessed in order to initially fit the NASA technologies within industrial sectors are publications by:

- U.S. Department of Commerce, Bureau of the Census
- U.S. Department of Labor, Bureau of Labor Statistics
- U.S. Department of Labor, Bureau of Economic Analysis
- Standard and Poor's Corporation
- Moody's
- Value Line
- OMB (SIC) Manual



This data was used to develop business, operating and structural profiles for the industrial sectors whose technology needs and interests correspond to the selected NASA technologies.

The business profile contains financial data, employment characteristics, productivity measures. The operating and structural profiles contain information regarding company size, manufacturing process, R&D involvement, key technologies being pursued in the near and medium term. Taken together, these profiles provide substantive information as to what the particular industrial sector is doing, how it is presently faring financially, what its prospects are for the future.

The ultimate purpose of the industry profile is to evince the technological requirements of the industrial sector under examination. For example, the aerospace industry's need for improved materials, such as composite structures and resins, stands out and is highlighted in Table 2, drawn from the profile of the Aerospace Industry, exemplified in Appendix F. The profile also provides important information affecting the introduction and use by industry of advanced technologies: e.g., business parameters, resources available and required, growth trends, productivity factors.

As a result of the analysis of the industrial use and need for advanced technologies, the following seven high-leverage technology areas, culled from the thirteen RTOPs initially chosen, were selected as candidates for further investigation. Compare with Table 1.

- Materials/Composites
- Automation Technology/Robotics/Teleoperators
- Power Conversion and Distribution
- Electrochemical Energy Conversion/Storage
- Non-Destructive Evaluation
- Tribology (Surface Science)
- Photovoltaic Energy Conversion

#### **Preliminary Industry-Oriented Analysis of Field Center Data**

The technology characterizations resulting from the Field Center contacts, were evaluated in the light of the industry profiles.

TABLE 2  
NEW AEROSPACE TECHNOLOGIES

TECHNOLOGY	DESCRIPTION	PRINCIPAL IMPACT	APPROXIMATE ERA OF SIGNIFICANT DIFFUSION			
			1985	1990	1995	2000
<b>AERODYNAMICS</b>						
<b>COMPUTATIONAL AERODYNAMICS</b>						
● STAGE 1	LINEARIZED INVISCID COMPUTATIONS FOR ATTACHED AIRFLOWS FOR SUBSONIC AIRCRAFT INCLUDING VORTICES AND BOUNDARY LAYER INFLUENCES	AIRCRAFT DESIGN, FLOW VISUALIZATION				
● STAGE 2	NON-LINEAR INVISCID (EULER) COMPUTATIONS INCLUDING TRANSONIC AND HYPERSONIC FLOWS, AND BOUNDARY LAYER INFLUENCES	AIRCRAFT DESIGN, TURBULENT FLOW REDUCTION, FLOW VISUALIZATION				
● STAGE 3	REYNOLDS AVERAGED NAVIER-STOKES COMPUTATIONS THAT CAN INCLUDE SEPARATION, LARGE ANGLES OF ATTACK, UNSTEADY FLOWS, EXTERNAL AND ENGINE FLOW INTERACTIONS	AIRCRAFT DESIGN, TURBULENT FLOW REDUCTION, FLOW VISUALIZATION				
● STAGE 4	FULL NAVIER-STOKES CAPABILITIES TO COMPUTE TURBULENCE. CAN INCLUDE AERODYNAMIC NOISE, TRANSITION, SURFACE PRESSURE FLUCTUATIONS, AND TURBULENCE INTENSITIES	AIRCRAFT DESIGN, TURBULENT FLOW REDUCTION, FLOW VISUALIZATION				
<b>LAMINAR FLOW CONTROL TECHNOLOGY</b>						
● NATURAL LAMINAR FLOW	LAMINAR FLOW OVER WING AND FUSELAGE RESULTING FROM SMOOTHER SURFACE FINISH OR MODIFIED WING STRUCTURE	TRANSPORT AIRCRAFT 30% FUEL SAVINGS/RANGE EXPANSION				
● MECHANICALLY INDUCED LAMINAR FLOW	SMALL HOLES ON LEADING EDGE OF WING ALLOW TURBULENT BOUNDARY LAYER TO BE REMOVED	TRANSPORT AIRCRAFT 30% FUEL SAVINGS/RANGE EXPANSION				
<b>STRUCTURES AND MATERIALS</b>						
● ALUMINUM TITANIUM ALLOY	LIGHT WEIGHT, HIGH STRENGTH ALUMINUM ALLOY	REDUCE STRUCTURAL WEIGHT				
● EPOXY	LIGHT WEIGHT, HIGH STRENGTH RESIN MATRIX MATERIAL	REDUCE STRUCTURAL WEIGHT				
● ADVANCED FIBER EPOXY	LIGHT WEIGHT, HIGH STRENGTH RESIN MATRIX MATERIAL	REDUCE STRUCTURAL WEIGHT				
● POWDERED METALS	ALLOWS PRODUCTION OF UNUSUAL ALLOYS AND SUPERALLOYS	REDUCE STRUCTURAL WEIGHT IMPROVE STRENGTH TO WEIGHT RATIO OF CERTAIN METALS				
● THERMO PLASTICS/ ADVANCED EPOXIES	HIGH TEMPERATURE, LIGHT WEIGHT, HIGH STRENGTH COMPOSITES	REDUCE STRUCTURAL WEIGHT, INCREASE STRENGTH				
● METAL MATRIX COMPOSITES	HIGH TEMPERATURE, LIGHTWEIGHT, HIGH STRENGTH METAL MATRIX COMPOSITES: CARBON OR CARBIDE FIBERS IN METAL MATRIX	REDUCE STRUCTURAL WEIGHT				
● CERAMICS	HIGH TEMPERATURE, HIGH STRENGTH ENGINE COMPONENTS	REDUCE WEIGHT, INCREASE THERMAL EFFICIENCY				
<b>PROPULSION</b>						
● ADVANCED HIGH BYPASS RATIO TURBOFAN (CF6-80C/PW2037 (JT100))	ADVANCED TURBOFAN ENGINE ENCASED IN MORE AERODYNAMIC NACELLE FEATURING DIGITAL BLADE CLEARANCE CONTROL	REDUCE NOISE 5dB, REDUCE SPECIFIC FUEL CONSUMPTION 12% (1980 BASELINE), IMPROVE RELIABILITY AND DURABILITY				
● DIRECT DRIVE HIGH BYPASS RATIO TURBOFAN	ADVANCED TURBOFAN ENGINE (BPR=5.5) WITH DIRECT DRIVE COMPRESSOR	REDUCE NOISE, REDUCE SPECIFIC FUEL CONSUMPTION 15%				
● GEARED HIGH BYPASS RATIO TURBOFAN	ADVANCED TURBOFAN ENGINE (BPR=9) WITH GEAR DRIVEN COMPRESSOR FOR BETTER MATCH BETWEEN TAKEOFF AND CRUISE THRUST	REDUCE NOISE, REDUCE SPECIFIC FUEL CONSUMPTION 20%				
● HIGH SPEED TURBOPROP (MACH 0.72 TO 0.8)	ADVANCED HIGH SPEED, HIGHLY SWEPT, MULT-BLADED TURBO PROP	REDUCE SPECIFIC FUEL CONSUMPTION 30%				
<b>AVIONICS AND CONTROLS</b>						
● FULLY DIGITAL FLIGHT MANAGEMENT SYSTEM (FMS)	FMS INTEGRATES INSTRUMENT OUTPUTS, COMMUNICATIONS, ENGINE, AND ENVIRONMENT CONTROLS AND PROVIDES PILOT WITH WARNING FOR DANGEROUS TRANSIENTS	REDUCE CREW WORKLOAD, IMPROVE CREW EFFICIENCY, ELIMINATES NEED FOR TWO CREW MEMBERS FOR COPILOT AND COMMUNICATIONS				
● FIBER OPTICS	REPLACE ELECTRICAL SYSTEM WITH LINKS WITH FIBER OPTICS	REDUCE ELECTRICAL SYSTEM WEIGHT, INCREASE TRANSMISSION SPEED 1000 TIMES, ELIMINATE ELECTRICAL SYSTEM SUSCEPTIBILITY TO ELECTROMAGNETIC INTERFERENCE				
● MICROWAVE LANDING SYSTEM	FAA-DEVELOPED AIRPORT TRAFFIC AND AIRCRAFT NAVIGATION AID	REDUCE CREW WORKLOAD, REDUCE AIRPORT DELAYS AND AIR TRAFFIC LOADS				
● FLAT PANEL CATHODE RAY TUBE (CRT)	FLAT PANEL FLIGHT INFORMATION DISPLAY FOR IMPROVED RESOLUTION	REDUCE COCKPIT CLUTTER REDUCE CREW WORKLOAD				
● ALL ELECTRIC CONTROLS	ELECTRIC ACTUATORS	ELIMINATE HYDRAULICS, REDUCE WEIGHT, REDUCE COCKPIT CLUTTER BY ELIMINATING STEERING YOKES				
● INTEGRATED VLSI/VHSIC	VERY LARGE INTEGRATION (VLSI) OF INSTRUMENTS AND CONTROL UTILIZING VERY HIGH SPEED INTEGRATED CIRCUITS (VHSIC)	IMPROVE WEIGHT TO POWER RATIO 80%, REDUCE CREW WORKLOAD TENFOLD IMPROVEMENT IN RELIABILITY OF SIGNAL PROCESSING				
● ADVANCED BRAKES/ STEERING	LIGHTWEIGHT CARBON BRAKES COMPOSITE STEERING STRUCTURE	REDUCE RUNWAY LENGTH REQUIREMENTS				
<b>MANUFACTURING SYSTEMS</b>						
● SPIN FORGING	TWO SPINNING ROLLERS SHAPE SPINNING WORK PIECE (FOR SOLIDS OF REVOLUTION)	REDUCE COMPONENT WEIGHT REDUCE ADDITIONAL MACHINING				
● FLEXIBLE MANUFACTURING	AUTOMATED WORK CELL CONSISTING OF COMPUTERIZED NUMERICALLY CONTROLLED MACHINING OPERATIONS WITH ROBOTICS TRANSFER MECHANISMS - ADAPTABLE TO SMALL BATCH PROCESSES	INCREASE PRODUCTIVITY				
● INTEGRATED MANUFACTURING SYSTEM	FMS WITH DIRECT LINK TO CAD COMPUTERS	INCREASE PRODUCTIVITY, ENABLE DESIGNER TO UPGRADE PART DESIGN WHILE ON-LINE				

The purpose of this evaluation was to bound, if possible to pin-point, the gamut of applicability of the selected technologies within specific areas of paramount interest to industry. For example, the research being conducted by NASA in the technology of Remote Manned Control, see Table 1, is specifically oriented towards optimizing the performance of teleoperators in various space applications, e.g., assembly of large structures from within a manned space station. The research is investigating techniques of sensing, communications, and display of information. The industrial interest in teleoperators is narrower: it is primarily centered on sensory feedback, i.e., techniques for presenting operators with realistic portrayals of remote situations. Thus, sensory feedback is the particular aspect of this NASA research which is the best candidate for technology transfer to industry.

The findings of the evaluation, by relevant industry sectors, including pertinent action items to further test our findings, were as indicated in Table 3.

TABLE 3

SUMMARY OF PRELIMINARY INDUSTRY-ORIENTED ANALYSIS  
OF FIELD CENTER DATA

**1. Materials/Composites**

- Langley's technology in composites fits several manufacturing sectors. Because of its high current cost, the most likely sector is Aerospace.
- A major aerospace company should be contacted to determine the status of Langley's technological lead in composite aerospace materials, particularly graphite composites.
- If the selected aerospace company should respond negatively, Langley technology should be explored with smaller industries engaged in producing highly stressed parts, e.g., reciprocating components, weavers' shuttles, engines, rotating machinery.
- A major producer of graphite fibers should be contacted to assess the sophistication of their product with respect to Langley's research and development.

TABLE 3 (Continued)

**2. Automation Technology/Robotics/Teleoperators**

- Langley appears to be ahead of industry in the systems approach; about even with industry in the development of hardware.
- The key area of technology of potential interest to industry is sensory feedback.
- Although the research being performed at Langley is basic to both industry and NASA, the ultimate applications differ. In general automation, industry aims at getting the man out of the loop; Langley's work is aimed at maintaining man in the loop for space operations.
- However, Langley's research could be very valuable for terrestrial operations in hostile environments, e.g., military, nuclear, fire fighting, underwater salvage, mining. Therefore, industries to be focused on should fall into these latter categories.
- Companies such as IBM and Unimation, and several universities are pursuing the systems approach to teleoperations. This means that two industrial focus points ought to be investigated: a) potential users of teleoperator techniques; b) current researchers in the field.

**3. Power Conversion and Distribution**

- The research ongoing at Langley in solar-laser generation and reception appears to be suitable only to space uses, because of low conversion efficiency.
- Of potential industrial interest is Langley's gas-operated high current switch. If this device performs as indicated in our contacts with the NASA researchers, it could apply to electric power utility circuit-breaker switches, switches for cyclotrons and synchrotrons, and other very high current switching applications.

TABLE 3 (Continued)

**4. Electrochemical Energy Conversion/Storage**

- There appears to be no industrial market for the current Lewis Research Center (LeRC) development in this area of technology. Very high reliability, needed for space application, is not required in terrestrial uses. Energy storage capabilities, adequate for space application, are too low for industrial usage.

**5. Non-Destructive Evaluation (NDE)**

- NDE technology is in significant demand by manufacturing industries.
- There is significant industrial interest in ultrasonic techniques.
- The main problem hindering commercialization of the technology is the high cost.
- Of particular interest is the evaluation of material "toughness", which is an emerging specialty in the field of materials science.

**6. Tribology (Surface Science)**

- The NASA technology looks good.
- Numerous industries are interested, particularly in the technological expertise evidenced by NSA researchers.
- The technology appears marketable, in that industry can be expected to pay money to interface with NASA on cooperative research projects.
- Needs to be followed, possibly by selecting specific products or techniques to be presented to industry.
- NASA appears to be in the forefront in this area of materials science.

TABLE 3 (Continued)

**7. Photovoltaic Energy Conversion**

- Price is the big driver for terrestrial photovoltaic applications. Thus, reduction of price could capture the small appliance and other markets currently held by the Japanese, and perhaps create new markets for U.S. industry.
- A significant element of technology appears to be the solar concentrator. The reason is that, if it can be produced at sufficiently low prices, it could alleviate the high cost of gallium arsenide cells. What would also be desirable is a configuration which need not be steered to track the sun.
- Solar converters do not appear at this time to be a high national priority. This is because of the relaxation in the upward pressure on energy prices.
- An interesting future development might be the surface plasmon converter. NASA ought to investigate further how close it is to reality.

Our initial evaluation indicated that NASA's technology of Electrochemical Energy Conversion/Storage was the only one which did not appear promising for near-term industrial application. This reduced the seven technology areas initially identified to six:

- Materials/Composites
- Automation Technology/Robotics/Teleoperators
- Power Conversion and Distribution
- Non-Destructive Evaluation
- Tribology (Surface Science)
- Photovoltaic Energy Conversion

Nevertheless, we did survey industries using or producing electrochemical energy conversion and storage technologies in order to determine industry needs that future NASA research could perhaps meet.

### **Initial Queries to Potentially Interested Industries**

In order to verify industry's specific research activities and needs in the selected NASA technology areas, initial queries were made. These queries were directed to industries with potential interests in the technologies summarized in Table 3. Standard Industrial Classification (SIC) information that was consulted, along with our industry profiles, permitted us to identify industry sectors having the greatest potential for correspondence with the research activities of NASA. Leading companies from the appropriate industry sectors, identified by SIC Codes in Appendix G, were chosen to be queried, based upon our knowledge of each company's primary activity.

For the seven areas of technology, a survey of twenty companies with major interests in these areas was conducted. From our industrial experience, our industrial data files, data developed in such recent studies as the NASA New Look (Contract NASW-3864), and from the industry profiles developed under this effort, twenty applicable companies were selected. These initially selected companies were chosen from among establishments having extensive research and development facilities and R&D staff. Each of the twenty companies contacted was asked to express their current general needs and interests in the selected technologies. Names of the companies contacted are withheld for proprietary reasons.

The research personnel contacted were not particularly guided into the seven selected technology areas, but were just requested to offer specific comments concerning their needs, problems and interests. From these twenty contacts, a tabulation of almost fifty relevant comments was obtained that related directly to the seven selected areas of technology. A complete summary of this information concerning industry research activities is contained in Appendix G. As an example of the research activities shown in Appendix G that these companies expressed interest in, the following is provided:



### Area of Technology - Materials/Composites

<u>Research Activities</u>	<u>Generic Industry</u>	<u>SIC Codes</u>
* Molding techniques for application to composite materials	Aircraft Parts., Plastics Manufacturing	2869, 3079, 3728
* Impact modification of epoxy resins	Aircraft Parts, Sports Articles, Automobile Parts	2821, 3069, 3079, 3728

The "hit" record (similarity of technology interests) proved quite good, indicative that the AD approach to RTOPs selection and uncovering of NASA research areas correlated well with industry's research needs.

An important finding became evident during this phase of the investigation. It is very important for NASA's TU Office to communicate information about new technologies to industry in terms of industrial specifications and standards. If the transfer of new technology to industry is to be facilitated by NASA, this finding must be recognized and acted upon. This will be dealt with in detail in the next Chapter of this report.

### Role of Technology Utilization Officers (TUOs)

Before leaving this phase of our investigation, a few significant observations regarding the role of the TUOs from our visits to Langley and Lewis Research Centers are appropriate. The TUOs provided valuable assistance in arranging meetings with researchers at Field Centers for us. They also provided technical insight into the TU program, and supplied supplementary technical documentation.

The TUOs appear to provide timely coordination and quick response in facilitating contact between NASA and industry. As a general observation from the Field Center visits, the TUO program appears to be working well. The TUOs know the Field Center organizations and operations thoroughly at Langley and Lewis.

One finding that appears to have general application throughout the NASA TU community concerns budgetary allocations for TU activities. It was reported that only Langley has ever had such an allocation as a "line item". If all NASA Field Centers had

dedicated TU budgetary accounts, against which TU-oriented activity could be charged, much currently existing pressure would be relieved on the part of the technologist's management. This is because research personnel engaged in TU-oriented activities could make time (and materials) charges against the Field Center's TU budget, rather than against their normal research and development budgets.

## CHAPTER III

### ANALYSIS OF FINDINGS FROM NASA AND INDUSTRY SOURCES

#### **Need for Specification Sheets**

Our Applications Development (AD) approach thus far resulted in the selection of NASA research areas from which to uncover possible leading-edge technologies of interest to industry. Next we identified industrial sectors potentially interested in these technologies through the analysis of industry profiles. Following, we found that the technology opportunities developed from NASA sources corresponded with research activities that were of interest, according to our initial inquiry responses, to the companies contacted from the targeted industry sectors.

It remained to determine the extent of industry's specific interest, and to obtain definitive responses from representative companies, both users and producers, for each area of technology. This was required, because we knew that users and producers of each technology area being explored had differing needs and objectives. Normally, the user is a buyer of the technology; the producer is a seller.

During our initial inquiries, industry R&D personnel had difficulty interpreting the information that we had available regarding NASA's emerging technologies. Although all of the materials and technical information received from NASA researchers was good, we found it necessary to improve communication with industry by recasting it in terms and specifications that industry research personnel related to more readily.

Our initial contacts with industry revealed that they did not relate well to NASA's scientific or marketing-style documentation. Rather, we found that they more readily relate to the engineering-types of specifications and standards that prevail in their particular industry. These include the types of specifications approved by ASME, ASHRAE, SAE, IEEE, ASTM and the like.

Therefore, the technical monitors and researchers for the RTOPs of interest were contacted again. They were asked to provide specifications and standards concerning their work that we could appropriately recast for industry personnel. This step of providing usable specifications and standards in a format readily acceptable to industry, was absolutely essential to ensure more effective communication with industry.

## Development of Specification Sheets

This recasting was done by preparing a specification sheet (termed "spec. sheet" herein) for each of the NASA research areas to be investigated in more detail with industry. The only area for which a spec. sheet could not be prepared was Tribology, a basic scientific area without specific parameters to be called out. Spec. sheets, based upon NASA information that was recast into industry terms, were formulated for each of the other specific technologies prior to contacting targeted companies or technical organizations. Several scientific societies and industry associations were contacted during this effort, in order to verify the correctness of the format and terminology used in the spec. sheets. These spec. sheets, designed to highlight industry technology interests, were developed for the following NASA research areas:

<u>NASA RESEARCH AREAS - SPEC. SHEETS</u>	<u>INDUSTRY INTEREST</u>
1. Materials/Composites - Carbon Fiber Structures	1. High strength to weight structures
2. Teleoperators - Sensory Feedback	2. Remote control of hazardous processes
3. Power Conversion and Distribution - <u>Mega-Ampere Switch</u>	3. High power electrical switching
4. Non-Destructive Evaluation- High Resolution Ultrasound	4. High resolution micro- structure evaluation
5. Photovoltaic Energy Conversion - Solar Energy Concentrators	5. Generation of electric energy from solar energy

The information provided by NASA researchers was restructured and compactly formulated using engineering specifications and standards for the individual research areas listed above. The spec. sheets so formulated are contained in Appendix H. Two of these spec. sheets, one for Carbon Fiber Structures and one for High Resolution Ultrasound, are shown as examples in Figures 2 and 3. These two show clearly the format and types of specific information and data that are of interest and useful to

SPEC. SHEET  
FOR  
MATERIALS/COMPOSITES  
CARBON FIBER STRUCTURES  
(HERCULES AS 4 FIBER - 3501-5A PROG. RESIN)

ORIGINAL PAGE 13  
OF POOR QUALITY

**Composition by Elements:** 60% Carbon Fibers + 40% Resin - by weight  
Normal reference = "50-50" by volume.

**Shape, Form, and Condition of the Structure:** Can form any shape, especially when hard rigid shapes.

**Diameter of the Fiber:** 7 to 8 Microns (1/3 the diameter of human hair)

**Fiber Contents of the Composite Material:** Same as above.

**Strength of the Structure:**

Tensile: 400,000 to 500,000 psi  
Flexure: 260,000 psi  
Yield: Not much, but elongation = 1.3%  
Laminar Shear = 19,000 psi  
Hardness: Same as resin  
Density: 1.7 to 1.8 grams per cubic cm.  
Modulus of Elasticity: 34 to 35 Million psi  
Flexural Modulus:  $18.7 \times 10^6$  psi  
Tensile Modulus:  $20.7 \times 10^6$  psi

**Special Properties:**

<b>Thermal Expansion Coefficient:</b>	Longitudinal	-	0.1 to $0.2 \times 10^{-6}$
			inches/inch/ $^{\circ}$ F
	Cross fiber	-	$10-20 \times 10^{-6}$
			inches/inch/ $^{\circ}$ F

<b>Thermal Oxidate Resistance:</b>	Short term -	retain full strength up to $1,000^{\circ}$ C
	At $316^{\circ}$ C -	lose 0.18% of its weight during 700 hours

**Thermal Conductivity:** 0.032 Cal/cm/sec- $^{\circ}$ C

**Electrical Resistivity:** 1,500-5,000 ohms/cm/foot for 10,000 filament tow

**Volatile Contents If Any:** None

**Costs:** For continuous fibers = \$15 to \$20 per pound

**Applications:** NASA only

General:	Secondary structures, i.e., Boeing 757, 767 floors & spoilers, ailerons, rudders, and "filleting" (wing to body)
Special:	Spacecraft; i.e., platform for space telescope for thermal stability

**Special Remarks:** Expensive! Trying to get costs down--then more people will find uses.

FIGURE 2

SPEC. SHEET  
FOR  
NON-DESTRUCTIVE EVALUATION  
HIGH RESOLUTION ULTRASOUND

**Type (Submerged/Non-Submerged):** Use Both - Submerged-when piece can fit into tank because water is a better transmitter. All Others - Non-Submerged.

**Focused/Unfocused:** Both - Focused for better resolution. Unfocused for large areas fewer passes, faster scan.

**Frequency:** 1 To 100 Megahertz

**Band Size:** Broad-Depends on Frequency (5 to 50 Megahertz)

**Electric Pulse:** Short Duration - Spiked (Spiked/Rectangular/Other)

**TRANSDUCER/RECEIVER**

**Characteristics:** Barium Titanate

**Signal Processings:** Both Amplitude and Spectrum - Amplitude or "Time Domain" (Response to question simply helped define headings-Applications varied). Look at the Frequency Spectrum.

**Structure Size Probed:** 1/4" To 1" Diameter

**Costs:** Approximately \$ 75K for Tank & Peripheral Equipment & Computer to scan (not to store data).

**Applications:**

1. Metals/Alloys
2. Composites (Metals/Non-Metals)
3. Ceramics

**Remarks:** Major thrust in NASA is to determine material characteristics (Microstructure, etc.) Exclusive of flaws. Flaw detection important but plays small role in their work. Basic work in the R&D beyond state-of-the-art. Regarding industry comment "20 Micron Flaw detection"--if they can get that they are doing good work. Does not agree with industry comment that this method "can only detect flaws--not characteristics". His work can!

FIGURE 3

industry personnel. These "spec. sheets" contain pertinent information, recast from that made available by NASA researchers. It was known to be of interest to, or would awaken interest in, the targeted industry R&D personnel that we had selected to contact.

### **Industry Contacts Using Spec. Sheets**

Using the spec. sheets, appropriate user and producer companies were contacted, in order to ascertain industry interest levels for the specific NASA research areas. Use of the spec. sheets greatly facilitated industry cooperation and evoked specific responses in a timely manner. Without the spec. sheets, it had not been possible to obtain the high levels of interest that they precipitated from the industry researchers contacted. In every case, by using our spec. sheets to convey technical information, interest in NASA technology areas was heightened above the level previously attained.

The NASA technology opportunities that were discovered covered a spectrum of orientations for industry interest. Manufacturers of carbon fiber structures, mega-ampere switches, and solar energy concentrators are product oriented. Users of sensory feedback and high resolution ultrasound technologies are process oriented. Tribology, as related to surface science applications, is expertise oriented. However, user and producer viewpoints differ; therefore, the orientation of a company toward a new technology will depend upon the particular company's business objective. For example, a carbon fibers producer may have significant process orientation, while a manufacturer of high resolution ultrasonic equipment is more product oriented.

We understood and took into account these variations in the interests, needs, and objectives of industry, depending upon each company's orientation relative to each particular technology. We, therefore, purposely contacted both users and producers in the technology areas being investigated. This provided a more comprehensive expression of industry interest for each specific technology area.

For each of the six NASA technology areas, we contacted one or two appropriate users of the particular products of the new technology. As examples of users contacted: (1) The Boeing Company--Carbon Fiber Structures--such structures are used in aircraft structural members; (2) The U.S. Bureau of Mines--Sensory Feedback--experiments are underway using teleoperators for hazardous operations in mines; (3) The Baltimore Gas & Electric Company--Solar Energy Concentrators--a utility company that is interested in the development of economical solar electric power.



Also, for each area, at least one producer of materials or products for the new technology was contacted as follows: (1) Union Carbide Corporation--Carbon Fiber Structures--one of the leading manufacturers of graphite fibers; (2) Teleoperator Systems, Inc.--Sensory Feedback--a manufacturer of teleoperators with strong developmental efforts in the "telepresence" approach to man-machine remote operation; (3) Electric Power Research Institute--Solar Energy Concentrator--contacted as a proxy for producers, E.P.R.I. is the leader in solar concentrator research and development.

Responses obtained from industry, using the spec. sheets which were developed specifically to query research personnel, were positive. The companies and research activities contacted immediately expressed a high level of interest in NASA's research activity which we described to them. All confirmed their interest by asking for more information and/or additional future contacts regarding specific technologies. See Appendix I for a compilation of conversations with industry contacts. The spec. sheets facilitated communication, and industry contacts verified the validity of the selection process by their positive expressions of interest. This correlation is indicative of the positive results NASA could expect when using the new AD approach.

The matching of technologies developed under NASA's research program with appropriate industrial needs can be successfully accomplished by the prototype method used and described herein. Appendix I contains a complete record of the details of our contacts with industry personnel. The following summary of industry interest in the specific technology areas, that were identified from ECOsystems' investigations at NASA Field Centers, shows clearly where technology transfer "matches" were developed. Because of the differing needs and objectives of users and producers previously delineated, we contacted both for each specific technology area.

#### **1. Carbon Fiber Composite Structures**

**Producer:** Union Carbide Corporation is definitely interested in NASA's general research in carbon fiber structures. The specifics of their interest would depend upon the particular area of NASA research, and its potential for application by Union Carbide. Union Carbide has a large number of personnel working in various aspects of this area. In order to provide us specific NASA technology in carbon fiber composites throughout their organization for comments. For this purpose, they requested a copy of our spec. sheet.

**User:** The Boeing Company is a user of carbon fiber composites for secondary aircraft structures such as ailerons, rudders, etc. The major problem that Boeing has in use of composites is cost. They need (1990 time frame) new automatic tooling to reduce finished costs, and/or lower raw material costs. They recognize that costs will remain high as long as only small quantities of composite structures are being used. Boeing also sees the need for a thermoplastic resin to help alleviate manufacturing difficulties and reduce costs, by allowing molding of composite structures. Boeing believes they are ahead of NASA in testing of large structures, but behind in resin chemistry research. Boeing desires to continue working closely with NASA in the development of carbon fiber composite technology.

## 2. **Sensory Feedback (Teleoperators)**

**Producer:** Teleoperator Systems, Inc., is very much involved in this technology area. This small company has worked with NASA on a number of projects in the past and continually reviews NASA publications. They prefer to call their work "telepresence", and they would like to discuss specific areas of technology directly with NASA. The President of the company is active in industry and professional associations, and he desires very much to remain closely involved with NASA. The key technology here is sensory feedback.

**User:** Baltimore Gas & Electric Co. is interested in this technology area for application at their Calvert Cliffs nuclear power plant. They requested documentation of NASA technology from the spec. sheet. BG&E's main application for teleoperators is to prevent direct exposure of humans to nuclear radiation. They would be interested in "joining hands" with NASA for applicable technology transfer.

**User:** The Bureau of Mines has been doing considerable research work in robot applications for mining at their Robotic Research Group in Pittsburgh. They have been working closely with NASA in their programs to improve safety and productivity. They conduct actual usage tests by lending mining companies newly developed devices. They said they are interested in exploring NASA technology--particularly the control panel. Teleoperators prevent direct human contact with hazardous conditions. BuMines requested detailed descriptions of devices NASA is developing.

### 3. Mega-Ampere Switch

**Producer:** Electric Power Research Institute (EPRI) was contacted, as a proxy for producers, regarding NASA's development of gaseous, externally triggered, automatically activated switches that can turn on mega-ampere currents. All of EPRI's present research is devoted toward electric utility company applications. Although NASA's mega-ampere switch may not have an application for utility companies, EPRI was more optimistic about its application for lasers and cyclotrons. Experts in two electrical research and development fields at EPRI showed positive interest in cooperating with NASA researchers. They expressed a desire to use NASA's emerging electrical technology for commercial applications whenever possible. The head of the Electric Systems Division would like very much to meet with NASA researchers in his field to discuss emerging technology in HVDC transmission.

**User:** Baltimore Gas & Electric Co. was contacted regarding possible use of mega-ampere switches under development by NASA. They would be very interested in a similar switch to **turn off** (as a circuit breaker) mega-ampere currents. Such a device could save considerable money and space in BG&E's electric power applications. Since the switch presently under development by NASA is only useful to **turn on** mega-ampere currents, BG&E has no application for it.

### 4. High Resolution Ultrasound (NDE)

**Producer:** Hewlett-Packard Company is working with ultrasonic NDE as a tool, not as a product. Their primary area of NDE work is in medical instrumentation. Applications can vary, but the important thing is how their NDE equipment and techniques compare with those of NASA. They have a very positive attitude about NASA's R&D programs, and they would like to keep involved with whatever NASA is doing in this field. Hewlett-Packard would, however, need more specifics to become more active with NASA. They desire copies of the ECOsystems spec. sheet before commenting further.

**User:** The Boeing Aerospace Company personnel contacted use ultrasonic devices for materials testing during both inspection and research activities. They are currently using the S-80 reflectoscope which operates at 10 megahertz frequency. They were interested in learning that NASA is developing ultrasonic techniques for NDE equipment operating at frequencies up to 100 megahertz, but indicated that this provides very small flaw identification capability that is not currently required by Boeing. They indicated, however, that this new technology may be applicable to their future needs, and thus are very much interested in NASA's high resolution ultrasonic devices and technology. Boeing Aerospace personnel requested that detailed descriptive material be sent to them for study.

#### 5. **Basic Surface Science (Tribology)**

**Producer and User:** Since this is a technological area that covers a wide range of surface interactions subject to scientific investigation, it is an expertise resident in people rather than a technology subject to specifications. We contacted Exxon Corporation to discuss this area, since Mr. Don Buckley of LeRC had mentioned working with them in New Jersey a few years ago. Exxon expressed interest in all four areas of LeRC research: adhesion, friction, wear, and lubrication. Basic scientific investigations underway to determine the material properties controlling these four parameters are all candidates for cooperative work with Exxon researchers. The technological developments associated with lubrication, such as oil for automobile engines and the vast array of additives for this oil, are of primary interest to Exxon, the world's largest integrated oil company. Exxon considers that the work NASA is doing in this field is excellent, and some NASA work is on the cutting edge of technology. They believe NASA is ahead of industry and desire to be kept informed.

#### 6. **Solar Energy Concentrators**

**Producer:** E.P.R.I., contacted as a proxy for producers, believes they are ahead of everyone on solar concentrator R&D. They realize that NASA is primarily space oriented and are very familiar with NASA's work at Field Centers. Since their terrestrial applications are different from space applications, primarily due to problems of "tracking" the sun, E.P.R.I. has its

focus on cell efficiency, at present, rather than solar energy concentrators. However, E.P.R.I. desires to work more closely with NASA, and they desire to be kept informed of any improvements NASA may make in either cell or concentrator efficiencies.

**User:** Baltimore Gas and Electric Company was contacted first, but they referred us to the Electric Power Research Institute (E.P.R.I.). BG&E's Director of Research said that the amount of solar energy available in Maryland does not seem to be enough for economical power generation. They are studying the problem of solar energy availability now. Most of their current R&D is solar-thermal.

### **Procedural Findings**

One major problem was noted when dealing with the large companies. These organizations are typically very structured and cumbersome to approach with technology questions. A company researcher may agree that NASA has exactly the new technology that he wants or needs. This does not mean, however, that company decision-makers and comptrollers will agree to initiate and fund this particular technology area. Many company executives may become involved in obtaining a decision for a company to join NASA in an emerging technology program. By contrast, a small company, whose president or C.E.O. is active in all phases of his company's operation, would typically arrive at a decision to participate very quickly.

The spec. sheets that ECOsystems prepared gave our investigators and industry researchers a better knowledge of just what specific research level NASA had attained in each technology area. The spec. sheets were found to facilitate our communication flow with industry and attained more productive results. They help to convert "general" technology transfer intentions into "addressable" markets. We believe they can be instrumental to eventual capture of joint technology development projects.

The spec. sheets provided much valuable information for company research personnel; and, during the final conversations with most of them, they asked to examine even more specifications in detail. They requested to talk with someone directly involved to determine how the specifications were derived and applied. Therefore, as expected, it was obvious that more follow-up with industry would be productive. It will be necessary to bring industry research personnel into direct contact with NASA

researchers before the technology transfer process in the selected technologies can proceed.

All industrial personnel contacted spoke in positive terms about NASA's work, regardless of whether the NASA research was directed toward space applications. The general outlook was that NASA would develop information useful to industry, provided someone completes the chore of adapting the NASA technology for industry use. In other words, all of the companies contacted **want to keep the door open** to NASA as a potential source of technological information.

The question of whether NASA is ahead, behind, or on a par with industry in a specific technology area is very difficult to assess. As previously stated, NASA's work is generally aimed at different objectives than those of industry. Research costs are seen differently at NASA and within industry, due to industry's profit motive. Then, too, there is a reluctance on the part of industry technologists to say they are ahead of a very respected research organization such as NASA. Therefore, exact comparisons of technology advancements, or the relative status of research developments, were difficult to obtain. The most prevalent response from industry was a positive expression of interest, along with a desire for more information.

## CHAPTER IV

### SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

#### A. Summary

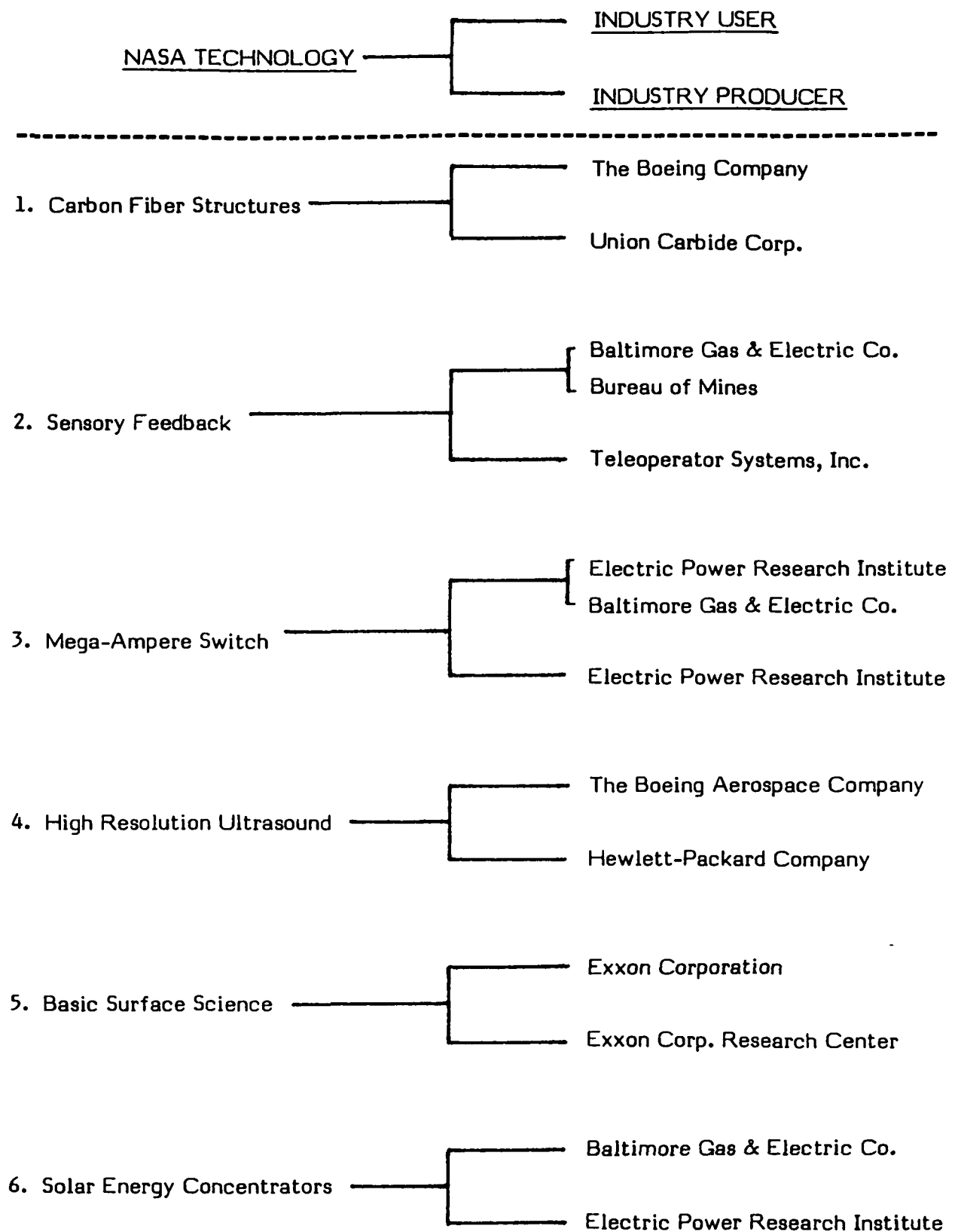
##### 1. Match Between Selected NASA Technologies & Industry Needs

The correspondence found between selected NASA technology developments and industry interests is as follows:

<u>NASA RESEARCH AREA</u>	<u>INDUSTRY INTEREST</u>
Materials/Composites	High strength to weight structures
Automation Technology/ Robotics/Teleoperators	Remote control of hazardous processes
Power Conversion & Distribution	High power electrical switching
Non-Destructive Evaluation (NDE)	High resolution micro-structure evaluation
Tribology (Surface Science)	Applications of surface science to reduced wear and friction, abrasive machining, adhesion
Photovoltaic Energy Conversion	Generation of electric energy from solar energy

##### 2. Test of the Validity of the Match

The degree of the matching interests in the above areas was found to be excellent, as shown by the positive responses given by the companies contacted. There was interest expressed in the selected areas of NASA research by each company and organization contacted. Figure 4 shows the companies and organizations that were contacted.



TECHNOLOGY MATCH-UPS WITH USERS/PRODUCERS

FIGURE 4



### 3. Problems Encountered and Lessons Learned

While accomplishing the above technology match-ups, the following problems were encountered and lessons were learned:

- It is difficult to schedule meetings with NASA researchers, in order to seek out innovations at their origin, unless you are an "insider". This appears to be linked to supervisory reluctance to expend budgetary R&D time on technology transfer activities.
- In the larger companies it is generally difficult to locate research people who also have decision-making authority. Sophisticated knowledge of industry, as well as time, effort, and persistence are required to work out a cooperative technology transfer program between NASA and a very large company.
- Smaller companies, with executives who are cognizant of and familiar with all aspects of their company's R&D efforts, are able to make technology utilization decisions expeditiously.
- The TUO program is working well for NASA at both Langley Research Center and Lewis Research Center.
- The **Tech Briefs** quarterly journal, **Spinoff** magazine, and the RTOPs annual summary are accomplishing the objectives for which they were designed. However, they could be profitably supplemented by initiating a means of publishing selected new NASA technologies in terms of industry specifications and standards.

### 4. Objectives Accomplished During the Performance of Task 6:

- Identification of high-leverage industrial areas that were determined to have valid technological needs which could be targeted for help from NASA's emerging technologies.
- Identification of "leading edge" NASA technologies that could meet industry needs in the targeted areas.

- Development of specification sheets for new NASA technologies. These were restructured and cast in industry terms to facilitate querying companies for comments concerning "leading edge" NASA technologies.
- Assessment of the level of interest generated by the new NASA technologies with industry R&D personnel, as a result of discussions based upon our specification sheets.

## 5. Assessment of the New Applications Development (AD) Approach

The development and testing of the above objectives proved the feasibility of the new approach offered by the prototype system. The AD approach does appear to have the capability to significantly enhance the overall effectiveness of NASA's technology utilization process. It is evident from our test results that considerable time can be saved in effecting "leading edge" technology transfers by: 1) efficiently and productively identifying high-leverage NASA/industry technology match-ups early-on during NASA's research efforts; and 2) facilitating technical dialogue between industry and NASA researchers, as early in selected research programs as possible. The key tool for this was found to be the spec. sheets. These two objectives are key elements that were successfully tested by ECOsystems during the conduct of this Task. It would therefore be beneficial for NASA, U.S. industry, and for the nation for NASA to incorporate the new approach into their current TU program.

## B. Conclusions

- The innovative Applications Development (AD) approach enhances the probability of earlier and smoother transfer of high-leverage/leading-edge technology from NASA to industry.
- The three elements which are key to implementing the AD approach are: 1) in-depth knowledge of industry and of industrial needs and concerns; 2) extensive in-depth knowledge of industrial technologies; and 3) familiarity with advanced and emerging NASA technologies.
- Industry understanding of, and interest in, NASA technology is greatly increased by structuring NASA's published research information into specifications and standards commonly used, accepted, and understood by U.S. industry; e.g., ASME, ASHRAE, SAE, ASTM, IEEE.

- The AD approach should reduce by several years the length of time normally required to effect technology transfers from NASA to industry.
- The AD approach tested would complement NASA's current TU role. It would not replace the established TU organization and mechanisms.
- The data and information produced by the tested approach could serve to profitably fine-tune NASA's RTOPs to increase their industrial orientation, without unduly affecting NASA's primary research mission.
- To implement this AD approach successfully, NASA must utilize its best expertise and in-depth experience in relating the value perceptions of industry to the outlook of NASA's researchers.

### C. Recommendations

The **principal recommendations** resulting from the conduct of Task 6 are:

- NASA and industry would benefit significantly from implementing the innovative AD approach developed by NASA's TU Office and ECOsystems.
- An important element of the implementation would be to supplement the current TU "Tech Briefs System". This should be accomplished by communicating selected technologies in terms of specifications and standards that are easily understood and commonly accepted by industry.

**Additional recommendations** resulting from observations during this effort are:

- Consider providing TU activities at Field Centers with appropriate budgetary means to better accomplish the TU mission. An important need is a budget to which Center researchers can charge time spent in interfacing with industries.
- Consider establishing a procedure whereby NASA's TU Office can fine-tune RTOPs in order to enhance the industrial orientation and eventual commercial application of the research.

APPENDIX A

NASA TECHNOLOGY UTILIZATION PROGRAM

## APPENDIX A

### NASA TECHNOLOGY UTILIZATION PROGRAM

This Appendix describes the current NASA organization and the procedures followed in order to effect technology utilization with U.S. Industry. It is included for the purpose of providing a background and setting for the new approach that was developed, tested, and reported. The responsibilities, procedures, and publications described in this Appendix have been referred to in this report as the Tech Briefs system of technology transfer.

Since its inception, NASA has been a primary source of concepts and technologies for U.S. industry. The direct transfer and use of these new technologies has been, and still is, of significant benefit in such areas as national defense, civil aviation, communications, and natural resource exploration and management. In addition to these direct benefits, NASA has learned over the past 22 years that it is possible to apply technologies, which have been developed for the Agency's primary mission, to other widespread "secondary" benefits. The results of this effort -- the measure of their success for NASA -- are in the form of visible changes: new and improved products and processes.

The NASA Technology Utilization (TU) Program seeks to increase public and private sector benefits by broadening and accelerating the secondary application of aeronautical and space technology. Through this TU program, NASA helps American industry in the private sector by getting aerospace technology out of the storehouse and into the mainstream of the national economy. This technology transfer program has been remarkably successful with literally thousands of technology transfers having been effected, since the TU program was established in 1962.

NASA's Technology Utilization (TU) organization has functioned in accordance with the lines of authority shown in Figures 1 and 2. Although NASA Headquarters is reorganizing, a similar set-up will exist. As shown in Exhibit 1, LG manages the TU network and coordinates the activities of NASA's technology transfer specialists located throughout the U.S. This network provides a link between the developers of emerging technologies and those who might effectively use it. The jobs of the TU specialists involve keeping abreast of aerospace technical advances, identifying new ways to employ the emerging technology productively, promoting interest among prospective users, and providing assistance to expedite the technology transfer process.

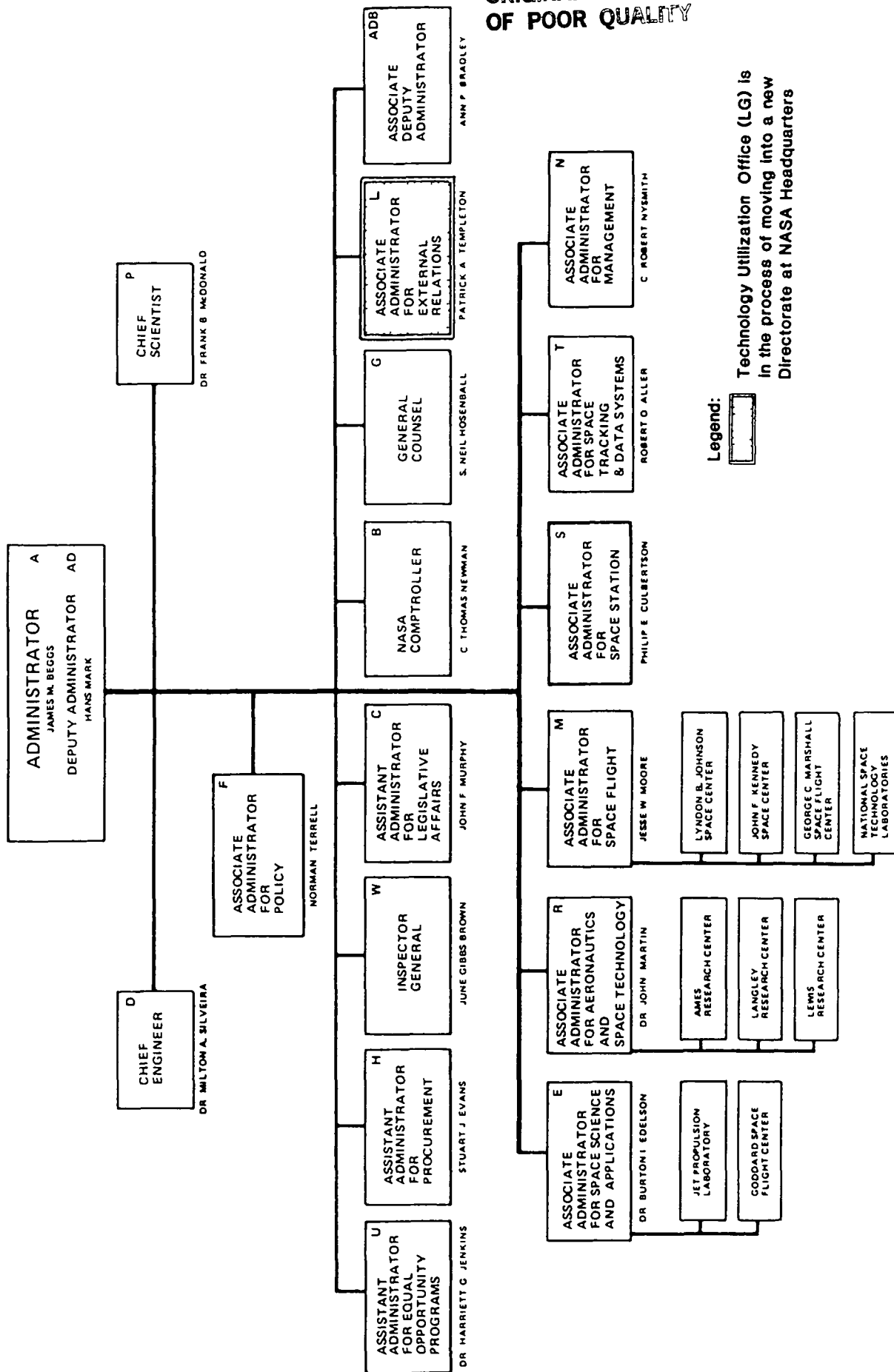


Figure 1. NASA Organization (September 1984)

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The organizational chart is structured as follows:

- OFFICE OF THE ADMINISTRATOR**
  - OFFICE OF SPACE FLIGHT**
    - OFFICE OF SPACE SCIENCE AND APPLICATIONS**
      - NASA RES OFF** (J. L.)
      - TUO** (A. Smith)
      - JET PROPULSION LABORATORY**
        - GENERAL COUNSEL** (D. Fowler)
        - PATENTS AND TUO** (H. S. Johnson)
        - TUO DISSEMINATION** (J. English)
        - ENERGY & TECH APPLICATIONS** (G. Trubelhorn)
        - TECHNOLOGY APPLICATIONS** (W. Smith)
        - TUO APPLICATIONS** (T. Petersen)
      - GODDARD SPACE FLIGHT CENTER**
        - ENGINEERING** (J. H. Bonister)
        - ART/RT NAT. NEEDS** (D. S. Friedman)
        - TUO (Friedman)** (D. S. Friedman)
      - AMES RESEARCH CENTER**
        - ASTRONAUTICS** (D. E. Wilson (Debl))
        - ANTONINE MISSIONS & APPLICATIONS** (M. A. Krutson)
        - TUO** (B. D. Pedrick)
      - LANGLEY RESEARCH CENTER**
        - MANAGEMENT OPERATIONS** (J. F. Stokes)
        - RESEARCH INFO & APPLICATIONS** (J. G. Rose)
        - TUO** (J. Brown)
      - LEWIS RESEARCH CENTER**
        - EXTERNAL AFFAIRS** (J. E. Burgett)
        - TUO** (H. Allen)
      - LYNDON B. JOHNSON SPACE CENTER**
        - PATENT COUNSEL LEGAL OFFICE** (M. F. Mathew)
        - TUO** (W. Chmielek)
      - JOHN F. KENNEDY SPACE CENTER**
        - SPACE STATION & PROO SUPPORT PROGRAM** (R. H. Gray)
        - TECHNICAL PROJECTS** (J. M. Spenser)
        - TUO** (U. R. Barnett)
      - GEORGE C. MARSHALL SPACE FLIGHT CENTER**
        - ADMINISTRATION & PROO SUPPORT** (J. N. Foster)
        - TUO** (J. Albery)
      - NATIONAL SPACE TECHNOLOGY LABORATORIES**
        - CHIEF COUNSEL** (E. Long)
    - OFFICE OF AIR AND SPACE TECHNOLOGY**
      - AMES RESEARCH CENTER**
        - EXTERNAL AFFAIRS** (J. E. Burgett)
        - TUO** (H. Allen)
      - LANGLEY RESEARCH CENTER**
        - MANAGEMENT OPERATIONS** (J. F. Stokes)
        - RESEARCH INFO & APPLICATIONS** (J. G. Rose)
        - TUO** (J. Brown)
      - LEWIS RESEARCH CENTER**
        - EXTERNAL AFFAIRS** (J. E. Burgett)
        - TUO** (H. Allen)
      - LYNDON B. JOHNSON SPACE CENTER**
        - PATENT COUNSEL LEGAL OFFICE** (M. F. Mathew)
        - TUO** (W. Chmielek)
      - JOHN F. KENNEDY SPACE CENTER**
        - SPACE STATION & PROO SUPPORT PROGRAM** (R. H. Gray)
        - TECHNICAL PROJECTS** (J. M. Spenser)
        - TUO** (U. R. Barnett)
      - GEORGE C. MARSHALL SPACE FLIGHT CENTER**
        - ADMINISTRATION & PROO SUPPORT** (J. N. Foster)
        - TUO** (J. Albery)
      - NATIONAL SPACE TECHNOLOGY LABORATORIES**
        - CHIEF COUNSEL** (E. Long)
    - OFFICE OF THE GENERAL COUNSEL**
      - PATENT COUNSEL** (R. Kemper)
    - OFFICE OF MANAGEMENT**
      - INVENTIONS & CONFIRMATIONS BOARD** (F. Lane, Chm.)
      - DIR. LOGISTICS, MOAT & INFO PROGRAMS DIV** (R. J. Pelton)
      - CHIEF SCI & TECH INFORMATION** (L. Audit)
      - DISSEMINAL & ANALYSIS** (L. Audit)
      - TERRSTRIAL APPLICATIONS** (R. Whitten)
      - INDUSTRY CONFERENCES** (J. H. Hurd)
    - EXTERNAL RELATIONS** (P. A. Tenthorian)
      - TU & INDUSTRY AFFAIRS** (R. J. Pelton)
      - TECH. BRIEF PREPARATION (ITS CORP)** (G. Oates)
      - NEW TECHNOLOGY EVALUATION (ERI INTERNATIONAL)** (R. Lipe)
      - TECHNOLOGY APPLIC. TEAM (HES. TRI INST)** (D. Rouse)

**Legend**

- Technology Utilization (Headquarters)
- Technology Utilization Officer
- Technology Counselors

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RESPONSIBILITIES AND FUNCTIONS OF L, LG, AND LGT

ASSOCIATE ADMINISTRATOR FOR EXTERNAL RELATIONS (L)

(From NMI 1103.15E, 18 Nov 83)

- a. Provide executive leadership, direction, and coordination of public affairs, international affairs, DOD affairs, other Federal agency affairs, state and local government affairs, industry affairs, academic affairs, the technology utilization program, and television development.
- b. Advises the Administrator on all matters involving the external relations of the agency, except for matters relating to the Congress and the Office of Management and Budget.
- c. Assists the Program Associate Administrators and Center Directors in planning, arranging, and evaluating cooperative participation in the conduct of programs involving NASA and other organizations.
- d. Provides the Secretariat and related support for the Aerospace Safety Advisory Panel and the NASA Advisory Council.
- e. Provides the Secretariat and related support for the NASA council and manages NASA's long range planning process under the Council's direction.
- f. Provides for approval and evaluation of NASA historical programs and activities.
- g. Provides for analysis of the financial, social, and economic impacts of NASA's R&D activities.
- h. Provides such other assistance or support as may be directed by the Administrator.

DIRECTOR, TECHNOLOGY UTILIZATION AND INDUSTRY AFFAIRS (LG)

(From NMI 1103.30A, 8 Jan 81)

- a. Initiates, plans, and coordinates policies, programs, and procedures designed to elicit effective and appropriate cooperation between and among NASA, other civilian federal agencies, state and local government, industry, and related interest groups.
- b. Coordinates the development of interagency and cooperative intergovernmental agreements designed to facilitate use by NASA of equipment, facilities, competence, and sites of other civilian federal agencies, state and local governments, and industry; and the use by these entities of NASA equipment, facilities, competence, and services.



DIRECTOR OF TECHNOLOGY UTILIZATION AND INDUSTRY AFFAIRS (LG)  
(Continued)

- c. Advises the Administrator and the principal staff on the progress and impact on NASA of interagency, intergovernmental, and industrial policies, plans, programs, and requirements; and on the impact of NASA policies, plans, and programs on these sectors.
- d. Establishes and facilitates the development and maintenance of effective and appropriate communications arrangements with other civilian government entities, industry, and interest groups in order to assure adequate consideration of NASA programs, plans, and responsibilities by these institutions, and in order to identify their policies, plans, and programs that are of interest to NASA. Handles inquiries, initial approaches, and general issues from and with these sectors, and consults with or refers such questions or issues to the program and staff offices as desirable or necessary.
- e. Participates fully with the program and staff offices involved in the exploration and negotiation steps which lead to informal/formal agreements on programs and projects with other mission agencies. Take as supporting role in following up program and project implementation to assure good relationships, compliance with the terms and spirit of the agreement, and for feedback purposes.
- f. Contributes to all of the above responsibilities and relationships with the program offices a concern for national and agency policy guidelines, relatively independent of program office objectives, ensuring that policy issues are surfaced as may be necessary for senior management consideration; for example, where technical, business or project considerations may appear to conflict with policy commitments.
- g. Provides for appropriate NASA representation to other federal agencies on matters concerned with interagency, intergovernmental, and industry plans, policies, procedures, and programs.
- h. Provides an objective perspective on and responsive interest in (ombudsman role) problems and opportunities which other agencies and industry may have with NASA, and assures that their views on the issues involved have been considered by the program and staff offices and that proper action results.
- i. Provides policy guidance for NASA involvement in Intergovernmental Personnel Act assignments.
- j. Chairs, coordinates, and supports, as appropriate, task forces, committees, and working groups charged with studying policies, plans, programs, and procedural issues in the intergovernmental, interagency, industry, and interest group areas.

EXHIBIT 1 (Continued)

CHIEF, DISSEMINATION AND ANALYSIS (LGT)

From PD for Chief, Program Control and Evaluation Division,  
13 Jun 73 as modified by NASA, Code I,  
information sheet of 1 Oct 84 for current responsibilities and functions)

- a. Responsible for Agency-wide functions designed to promote the secondary use of aerospace-developed technologies in U.S. industry, including the following.
- b. Establishment and implementation of policies and procedures for new technology acquisition and evaluation, including reporting requirements in all NASA R&D contracts and evaluation of new technologies identified, documented and reported to NASA.
- c. Establishment and implementation of policies and procedures for publication preparation and distribution, including management of NASA Tech Briefs journal and packaging new technologies in various media to facilitate use throughout U.S. industry.
- d. Establishment and implementation of policies and procedures for nationwide technology dissemination center network through NASA Industrial Applications Centers (IACs) and by providing for information interpretation and analysis to match industry needs.
- e. Manage and maintain the Computer Software Management and Information Center (COSMIC) to sell or lease NASA-developed computer software for secondary use by U.S. industrial firms.
- f. Establishment and implementation of policies and procedures for program evaluation by conducting functional and program analyses of technology transfer mechanisms and by conducting technology and industry profile analyses to determine unique transfer opportunities.
- g. Establishment and implementation of policies and procedures for space benefits and spinoffs by management of user follow-up process with industry applications.
- h. Publish annual report called "Spinoff" describing industrial uses made of aerospace derived technologies and technological impacts for public consumption.

CHIEF, TERRESTRIAL APPLICATIONS (LGT)

(From PD for Chief, Technology Applications Office, 9 Sep 82)

- a. Responsible for developing and implementing a technology utilization (TU) policy for NASA HQ, NASA Centers and outside users of NASA technology for the development of application engineering projects.
- b. Serves as the technical and management focal point with the HQ Program Offices and Center TU Offices to determine applications engineering opportunities evolving from the R&D base.
- c. Establishes and supervises procedures for Interagency and Industry applications project coordination and development.

- d. Supervises four employees and develops required performance appraisals. Manages and approves/disapproves project related travel of subordinates, T&A and leave requests. Approves, disapproves and/or cancels projects to meet agency near and long term goals.
- e. Develops nonsupervisory technical and management performance appraisal procedures for TU engineering staff and provides appraisals to Division Director on a semi-annual basis.
- f. Develops agency planning documents for applications engineering.
- g. Develops program evaluation procedures and models for tracking effectiveness and benefits of the TU engineering program.
- h. Develops materials for budget planning, Congressional and OMB briefings.
- i. Represents NASA, or delegate authority to subordinates, at all Interagency/Industry project meetings that are concerned with a secondary or primary use of NASA technology to solve a significant national or international problem.
- j. Responsible for developing ways to apply applications technology or knowledge to present and future aerospace missions.
- k. Coordinates intercenter, interagency and other joint ventures in providing solutions to complex technical problems required to meet national objectives by applying aerospace technology as a unique solution.
- l. Serves as the catalyst bringing together the expertise of diverse elements within and outside of the Agency.

EXHIBIT 1 (Continued)

Exhibit 1 depicts the responsibilities and functions of L, LG, and the two branches within LG. The Terrestrial Applications Branch focuses its attention on public sector problems of general public concern such as safety, health and environment. This branch facilitates the design, building, test and demonstration of prototype hardware as part of the problem-solving process working with Application Teams, the NASA Field Centers and hardware contractors. The Dissemination and Analysis Branch is primarily concerned with the transfer of technological information to industry in the private sector. More about this branch and the mechanisms of the TU network are contained in the following paragraphs.

Mechanisms employed in the TU network are depicted in Figure 3 and include:

- Tech Briefs, a quarterly (contracted out by NASA recently) publication that informs potential users of new technologies;
- Industrial Application Centers (IACs), a network of regionally located organizations through which potential users of innovations and inventions may avail themselves of NASA expertise;
- State Technology Applications Centers (STACs), which facilitate technology transfer to state and local governments;
- Technology Utilization Officers (TUOs), located at NASA field centers, who serve as regional program managers;
- Technology Counselors, who support the TUOs;
- Application Teams, who work with Federal agencies and health organizations to identify critical problems amenable to solution by NASA technology; and
- Program Evaluation, whereby the TU Program is continually monitored and feedback is obtained to ensure program viability.

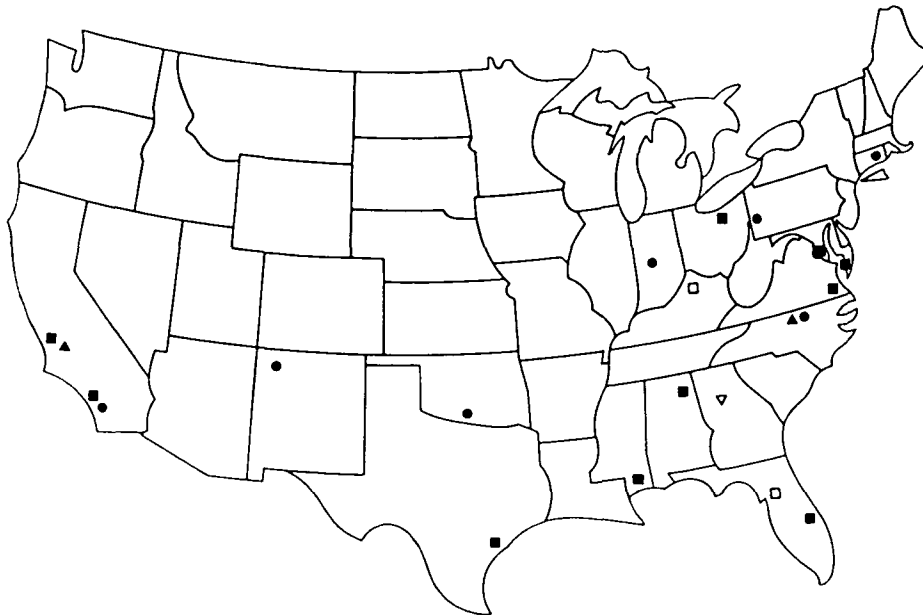
■ **Field Center Technology Utilization Officers** manage center participation in regional technology utilization activities

● **Industrial Applications Centers** provide information retrieval services and assistance in applying technical information relevant to user needs

□ **State Technology Applications Centers** provide technology transfer services similar to those of the Industrial Applications Centers, but only to state governments and small businesses within the state

▽ **The Computer Software Management and Information Center (COSMIC)** offers government-developed computer programs adaptable to secondary use

▲ **Application Team** works with public agencies and private institutions in applying aerospace technology to solution of public sector problems



### FIELD CENTER TECHNOLOGY UTILIZATION OFFICERS (TUOs)

**Ames Research Center and Dryden Flight Research Center**  
National Aeronautics and Space Administration  
Moffett Field California 94035

Technology Utilization Officer *Stan Miller*  
Phone (415) 965-6471

**Goddard Space Flight Center**  
National Aeronautics and Space Administration  
Greenbelt Maryland 20771

Technology Utilization Officer *Donald S. Friedman*  
Phone (301) 344-6242

**Lyndon B. Johnson Space Center**  
National Aeronautics and Space Administration  
Houston Texas 77058

Technology Utilization Officer *William Chymiak*  
Phone (713) 483-3809

**John F. Kennedy Space Center**  
National Aeronautics and Space Administration  
Kennedy Space Center, Florida 32899

Technology Utilization Officer *U. Reed Barnett*  
Phone (305) 867-3017

**Langley Research Center**  
National Aeronautics and Space Administration  
Langley Station  
Hampton Virginia 23655

Technology Utilization and  
Applications Programs Officer *John Samos*  
Phone (804) 865-3281

**Lewis Research Center**  
National Aeronautics and Space Administration  
21000 Brookpark Road  
Cleveland Ohio 44135

Technology Utilization Officer *Harrison Allen, Jr.*  
Phone (216) 433-4000 ext. 422

**George C. Marshall Space Flight Center**  
National Aeronautics and Space Administration  
Marshall Space Flight Center Alabama 35812

Director Technology Utilization Office *Ismail Akbay*  
Phone (205) 453-2223

**Wallops Flight Center**  
National Aeronautics and Space Administration  
Wallops Island Virginia 23337

Technology Utilization Officer *Gilmore H. Trafford*  
Phone (804) 824-3411, ext. 663

**Resident Office**  
**Jet Propulsion Laboratory**  
4800 Oak Grove Drive  
Pasadena California 91103

Technology Utilization Officer *Aubrey D. Smith*  
Phone (213) 354-4849

**National Aeronautics and Space Administration**  
National Space Technology Laboratories  
NSTL, Mississippi 39529

Technology Utilization Officer *Robert M. Barlow*  
Phone (601) 688-1929

**Figure 3. NASA Technology Utilization Network**

## INDUSTRIAL APPLICATIONS CENTERS (IACs)

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**Aerospace Research Applications Center**  
PO Box 647  
Indianapolis, Indiana 46223

*John Ulrich, director*  
Phone (317) 264-4644

**Kerr Industrial Applications Center**  
Southeastern Oklahoma State University  
Durant, Oklahoma 74701

*Tom J. McRorey, Ph D., director*  
Phone (405) 924-6822

**NASA Industrial Applications Center**  
701 LIS Building  
University of Pittsburgh  
Pittsburgh, Pennsylvania 15260

*Paul A. McWilliams, Ph D., executive director*  
Phone (412) 624-5211

**NASA Industrial Applications Center**  
University of Southern California  
Research Annex, 2nd Floor  
3716 South Hope Street  
Los Angeles California 90007

*Robert Mixer, Ph D., director*  
Phone (213) 743-6132

**New England Research Applications Center**  
Mansfield Professional Park  
Storrs, Connecticut 06268

*Daniel Wilde, Ph D., director*  
Phone (203) 486-4533

**North Carolina Science and Technology Research Center**  
Post Office Box 12235  
Research Triangle Park, North Carolina 27709

*James E. Vann, Ph D., director*  
Phone (919) 549-0671

**Technology Applications Center**  
University of New Mexico  
2500 Central Avenue, S E  
Albuquerque New Mexico 87131

*Stanley Morain, Ph D., director*  
Phone (505) 277-3622

## STATE TECHNOLOGY APPLICATIONS CENTERS (STACs)

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**NASA/Florida State Technology Applications Center**  
University of Florida  
500 Weil Hall  
Gainesville Florida 32611

*J. Ronald Thornton, director*  
Phone (904) 392-6626

**NASA/UK Technology Applications Program**  
University of Kentucky  
109 Kinkead Hall  
Lexington Kentucky 40506

*William R. Strong, manager*  
Phone (606) 257-6322

## COMPUTER SOFTWARE MANAGEMENT AND INFORMATION CENTER (COSMIC)

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**COSMIC**  
112 Barrow Hall  
University of Georgia  
Athens Georgia 30602

*John A. Gibson, director*  
Phone (404) 542-3265

## APPLICATION TEAMS

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**Research Triangle Institute**  
Post Office Box 12194  
Research Triangle Park, North Carolina 27709

*Doris Rouse, Ph D., director*  
Phone (919) 541-6980

**SRI International**  
333 Ravenswood Avenue  
Menlo Park, California 94026

*James P. Wilhelm, director*  
Phone (415) 326 6200 Ext 3520

New technical information emanating from all of NASA's aerospace programs is put into NASA's computer data bank at NASA Headquarters Computer Center (NHCC). For example, the National Aeronautics and Space Act requires NASA contractors to furnish written reports containing technical information about inventions, improvements, or innovations developed in the course of work for NASA. All of this information is screened for potential industrial uses. If the technical information does have potential use, it is screened, written-up, and published quarterly in Tech Briefs which are distributed free. The publication is a current-awareness medium for its many industrial readers. Each issue contains information on approximately 150 newly-developed processes, advances in basic and applied research, improvements in shop and laboratory techniques, new sources of technical data and computer programs. Tech Briefs are available to engineers in U.S. industry, business executives, state and local government officials and other qualified technology transfer agents. Within each quarterly edition of the Tech Briefs can be found such new things as potential commercial products, industrial processes, basic and applied research, shop and lab techniques, computer software, sources of technical data, and leading-edge aerospace concepts. These are published under such headings as electronic components and circuits, physical sciences, materials, mechanics, and fabrication technology. In addition, each issue contains a subject index and a cumulative index is published yearly, thereby increasing the "shelf-life" of the reported technology.

The magnitude of the new technical information in NASA's computer data bank is awesome. As of 1983, there were some 2 million documents entered, and accessions were being input at the rate of 5,000 documents per month. NASA's vast storehouse of accumulated technical knowledge, computerized for ready retrieval is a valuable resource for eight Industrial Application Centers (IAC) affiliated with universities across the country (see IACs, Figure 4). LGT funds these IACs so that their directors and staff can:

1. Solicit technical problems from clients in industry.
2. Search the NASA computer data bank for applicable documents
3. Search some 400 commercial data banks (e.g. Dialog) containing some 8 million documents.

4. Screen results of the search to insure compliance with requirements of industrial clients.
5. Finalize data and deliver it to the industrial client for payment of a nominal fee.

Intended to prevent wasteful duplication of research already accomplished, the IACs endeavor to broaden and expedite technology transfer by helping industry to find and apply information pertinent to a company's projects or problems. In addition to the retrospective searches described above, the IACs also provide current awareness searches consisting of tailored periodic reports designed to keep a company's executives or engineers abreast of the latest developments in their fields. (See IAC's, Exhibit 2) The IAC-conducted, computer-assisted literature searches culminate in a printed bibliography (usually containing abstracts) designed to assist industrial clients in identifying and evaluating research, products, and technologies in their areas of interest. Industrial clients initiate searches in two ways: one is by telephone to call for an appointment on a date when a representative of the industrial client can be present at the IAC while the search is conducted, and the other is to fill out a request form and return it to the IAC. Upon receiving the request form, the IAC will call the prospective client to discuss details and provide cost estimates. Normally, a bibliography is produced and delivered within ten days. In addition to the literature searches, an IAC will pass questions and data to Technology Counselors at NASA's Field Centers. These experts help search out answers when the inquiry is specific, well-defined and within the purview of the respective Field Center.

There are two State Technology Applications Centers (STACs) in Florida and Kentucky (see STACs, Figure 3) which supplement the IAC system. The STACs perform services similar to the IACs, but where the IAC operates on a regional basis, the STAC works within an individual state, to provide technology transfer to industry and state and local government agencies. (See STACs, Exhibit 2). Several state and local governments have become involved in these processes over the past 20 years: either as an expression of concern for economic and industrial development, with its attendant employment and tax base benefits, or as a means for helping secure a desirable new product or service for the improvement of governmental operations. This involvement has included both financial support and technical participation.



## DESCRIPTION OF IACs, STACs, COSMIC, AND TUOs

### INDUSTRIAL APPLICATIONS CENTERS (IACS)

Computerized information retrieval from one of the world's largest banks of technical data is available from NASA's network of Industrial Applications Centers (IACs). The IAC's give access to over 1,800,000 technical reports in the NASA data base and to more than 10 times that many reports and articles found in nearly 200 other computerized data bases. The major sources include:

- 750,000 NASA Technical Reports
- Selected Water Resources Abstracts
- NASA Scientific and Technical Aerospace Reports
- Air Pollution Technical Information Center
- NASA International Aerospace Abstracts
- Chem Abstracts Condensates
- Engineering Index
- Energy Research Abstracts
- NASA Tech Briefs
- Government Reports
- Announcements
- and many other specialized files on food technology, textile technology, metallurgy, medicine, business, economics, social sciences, and physical science.

The IAC services range from tailored literature searches through expert technical assistance:

- **Retrospective Searches:** Published or unpublished literature is screened, and documents are identified according to interest profile. IAC engineers tailor results to specific needs and furnish abstracts considered the most pertinent. Complete reports are available upon request.
- **Current-Awareness Searches:** IAC engineers will help design a program to suit specific needs. Selected monthly or quarterly abstracts on new developments in areas of interest are provided.
- **Technical Assistance:** IAC engineers will help evaluate the results of literature searches. They can help find answers to technical problems and contact scientists and engineers at appropriate NASA Field Centers.

### STATE TECHNOLOGY APPLICATIONS CENTERS (STACs)

Government and private industry in Florida and Kentucky can utilize the services of NASA's State Technology Applications Centers (STACs). The STACs differ from the Industrial Applications Centers primarily in that they are integrated into existing state technical assistance programs and serve only the host state, whereas the IACs serve multistate regions. Many data bases, including the NASA data base and several commercial data bases, are available for automatic data retrieval through the STACs. Other services such as document retrieval and special searches are also provided. (Like the IACs, the STACs normally charge a fee for their services.)

### COMPUTER SOFTWARE MANAGEMENT AND INFORMATION CENTER (COSMIC)

A vast software library is maintained by COSMIC - the Computer Software Management and Information Center. COSMIC gives access to approximately 1,600 computer programs developed for NASA and the Department of Defense and selected programs for other government agencies. Programs and documentation are available at reasonable cost. Available programs range from management (PERT scheduling) to information science (retrieval systems) and computer operations (hardware and software). Hundreds of engineering programs perform such tasks as structural analysis, electronic circuit design, chemical analysis, and the design of fluid systems. Other determine building energy requirements and optimize mineral exploration. COSMIC services go beyond the collection and storage of software packages. Programs are checked for completeness; special announcements and an indexed software catalog are prepared; and programs are reproduced for distribution. Customers are helped to identify their software needs; and COSMIC follows up to determine the successes and problems and to provide updates and error corrections. In some cases, NASA engineers can offer guidance to users in installing or running a program.

### TECHNOLOGY UTILIZATION OFFICERS (TUOs)

The Technology Utilization Officer (TUO) at each NASA Field Center is an applications engineer who can help industry make use of new technology developed at his center. He provides NASA Tech Briefs and other special publications, sponsors conferences, and arranges for expert assistance in solving technical problems. Technical assistance, in the form of further information about NASA innovations and technology, is one of the services available from the TUO. Together with NASA scientists and engineers, he can often help find and implement NASA technology to meet specific needs. Technical Support Packages (TSP's) are prepared by the center TUO's. They provide further technical details for articles in NASA Tech Briefs. This additional material can help industry evaluate and use NASA technology.

EXHIBIT 2 (Continued)

In addition to the seven IACs in California, Connecticut, Indiana, New Mexico, North Carolina, Oklahoma, and Pennsylvania, there is an eighth one at the University of Georgia which offers government-developed computer programs for reuse. This IAC, known as the Computer Software Management and Information Center (COSMIC), collects, screens, and stores computer programs developed by NASA and other government agencies. (See COSMIC, Figure 3) COSMIC contains more than 1,300 programs for such tasks as structural analysis, electronic circuit design, and chemical analysis. In addition to offering these programs at a fraction of their original cost, COSMIC also makes available for purchase (on microfiche or computer magnetic print tape) an annual indexed catalog of all programs in the inventory. (See COSMIC, Exhibit 2)

Another part of NASA's technology transfer system supervised by LGT takes place at NASA's nine Field Centers:

- Ames Research Center (ARC), which also supervises Dryden Flight Research Facility (DFRF),
- Goddard Space Flight Center (GSFC), which also supervises Wallops Flight Facility (WFF)
- Lyndon B. Johnson Space Center (JSC),
- John F. Kennedy Space Center (KSC),
- Langley Research Center (LaRC),
- Lewis Research Center (LeRC),
- George C. Marshall Space Flight Center (MSFC),
- Jet Propulsion Laboratory (JPL)
- National Space Technology Laboratories (NSTL)

At each of these Field Centers, and at DFRF, WFF, and NASA Headquarters, there is a Technology Utilization Officer (TUO). (See TUOs, Figure 4). His primary function is to accelerate the uses of new technology developed or known at his location. The TUO provides technical assistance in the form of information about NASA processes, techniques, innovations, and technology. He provides free Technical Support Packages (TSPs), when requested, which provide additional details about new developments, such as articles in the Tech Briefs. (See TUOs, Exhibit 2)

Supporting the IACs TUOs at the NASA Field Centers are Technical Counselors. These technology transfer experts were added to the TU network several years ago, in

order to increase the productivity of the TUOs and, in effect, to act as counselors to the TUOs. These Technology Counselors are selected from long-time performers in the TU program, so that their advice and counsel to the TUOs is of great value. In order to have funding for the Technology Counselors, it was necessary to increase certain IAC budgets and to have each Technology Counselor report administratively to an IAC, rather than to the Field Center that he supports (see Technical Counselors, Figure 2). Even though this arrangement tends to make the Technology Counselor captive to this IAC, he still performs a valuable service to his specific TUO, and to the TU program in general. The TUO-Technical Counselor system is a productive team of great value to NASA.

Another TU program mechanism is the Application Team concept (see Figure 3). Application Engineering Projects are conducted to help solve public-sector problems in such areas as safety, health, transportation, and environmental protection. Application Teams specialize in biomedical disciplines, engineering, and scientific problem solving. Staffed by professionals from various disciplines, these teams work with other Federal agencies health organizations, and scientific institutions to identify critical problems amenable to solution by the application of existing or emerging NASA technology.

The final mechanism in the current TU program is known as Program Evaluation. This critical mechanism consists of continual monitoring and feedback assessment, in order to ensure the viability of NASA's TU program. For example, each issue of Tech Briefs contains a reader feedback form, which actively solicits comments and suggestions on how LGT can better help to apply NASA innovations and new technology to the user's needs. The continual feedback from all sources is analyzed, and the resulting improvements are incorporated as quickly as possible.

In addition to their responsibilities and functions in the TU program, the Associate Administrator for External Relations (L), the Director of Technology Utilization and Industry Affairs (LG), and the Chiefs of Dissemination and Analysis (LGT) and Terrestrial Applications (LGT) play an important role in the FEDD (For Early Domestic Dissemination) program. This program is set forth in NASA Management Instruction (NMI) 2210.1, "Early Dissemination of Technical Information", which promulgates the NASA policy on the dissemination of NASA-developed technology having significant early commercial potential. Because U.S. leadership in certain product areas has been weakened by the rapid technical progress of other countries, it has been determined that the FEDD program for potential U.S. users, while taking steps to delay the export of such

information, is in the national interest. The wide and frequent use of formal NASA technical publications and documents to disseminate information, having significant commercial value to domestic users, is encouraged. Such publications and documents will be made available to any domestic user who agrees to abide by the provisions of the FEDD legend which will appear on the cover (see Exhibit 3).

#### FEDD (FOR EARLY DOMESTIC DISSEMINATION) LEGEND

The following legend shall be applied to all written information falling within the scope of NMI 2210.1 which is intended for release outside NASA.

##### FOR EARLY DOMESTIC DISSEMINATION

Because of its significant early commercial potential, this information, which has been developed under a U.S. Government program, is being disseminated within the United States in advance of general publication. This information may be duplicated and used by the recipient with the express limitation that it not be published. Release of this information to other domestic parties by the recipient shall be made subject to these limitations. Foreign release may be made only with prior NASA approval and appropriate export licenses. This legend shall be marked on any reproduction of this information in whole or in part. Date for general release \_\_\_\_\_

#### EXHIBIT 3

APPENDIX B

RECORD OF NASA RESEARCHER CONTACTS

## APPENDIX B

### RECORD OF NASA RESEARCHER CONTACTS

This Appendix contains questionnaires that were completed while discussing research efforts being conducted at NASA Field Center with RTOP principals. The numbers at the top of each questionnaire correspond with the selected RTOPs of Interest listed in order in Table 1. The completed questionnaires are included here to provide background information on the individual NASA researchers' projects that were selected for further investigation of promising areas of technology.

#1

#### QUESTIONNAIRE FOR RTOP PRINCIPALS

**NAME:** R.C. Goetz (talked to Louis Vosteen X2361)

**ADDRESS:** LARC

**TEL. NO.:** 804-865-2042

**CENTER/DEPARTMENT:**

**RTOP NUMBER:** W84-70026 (505-33-33)

**RTOP TITLE:** Composites for Airframe Structures

**RTOP FUNDING:** 4 Million (FY-'84)

**ESTIMATED PROGRAM DURATION:** 5 years but plan to continue

**WHEN DID PROGRAM START:** Approximately 1974

**NUMBER OF NASA PERSONNEL INVOLVED:** 60 man years

**ARE CONTRACTORS INVOLVED (INDUSTRIAL AND/OR ACADEMIC):**

Yes -both industry and universities - too many to list.

**OTHER NASA CENTERS INVOLVED:**

LERC - mostly for high temperature applications to engines.

**WHAT ARE OBJECTIVES OF THE PROGRAM:**

Understand the fundamental structural properties and relationship of powder metals. Underlying objective is to develop materials that have improved properties plus develop structural concepts for airframes.

**WHAT ARE KEY PARAMETERS THIS RTOP IS AIMED AT IMPROVING:**

More efficient structural alloys for future aircraft applications chiefly on polymeric matrices and understand their structural behavior.

**WHAT NASA SPACE OR AERONAUTICS PROGRAM IS RTOP AIMED AT:**

Generic to all aeronautics and spacecraft.

**IS THIS RTOP BASIC RESEARCH OR DEVELOPMENT:**

Basic research.

**DO YOU SEE AN INDUSTRIAL APPLICATION FOR THE PROGRAM RESULTS:**

Yes - first the airframe manufacturers (Boeing, Lockheed, McDonald Douglas, etc). Then to applications where high stiffness to low mass ratio's are advantageous such as reciprocating machinery, robotics, etc.

**WHERE DO YOU THINK YOU ARE WITH RESPECT TO INDUSTRY DEVELOPMENTS:**

Varies depending on specific application but generally on par or ahead.

**WHAT INDUSTRIES ARE WORKING IN THIS SAME AREA:**

All aerospace companies and materials suppliers such as Dupont, American Cyanamid, Union Carbide, Hexcell, Hercules.

**ARE THESE INDUSTRIES AHEAD OR BEHIND IN RESPECT TO WHERE YOU STAND:**

Industry concentrates on developing marketable materials, NASA is looking for more fundamental properties. In this sense, NASA is ahead.

**WHAT IS RTOP SCHEDULE FOR GENERATION OF RESULTS (IN TERMS OF SIGNIFICANT ACCOMPLISHMENTS/MILESTONES AND WHEN):**

Because this is basic research and a long range continuing program - milestones are not "programmed".

**ANY OTHER INFORMATION YOU MAY WISH TO VOLUNTEER:**



QUESTIONNAIRE FOR RTOP PRINCIPALS

**NAME:** R.C. Goetz (talked to Louis Vosteen)

**ADDRESS:** LARC

**TEL. NO.:** 804-865-2042

**CENTER/DEPARTMENT:**

**RTOP NUMBER:** W84-70135 (534-06-23)

**RTOP TITLE:** Composite Materials and Structures

**RTOP FUNDING:** 2 1/2 Million

**ESTIMATED PROGRAM DURATION:** 5 Years

**WHEN DID PROGRAM START:** FY 1982

**NUMBER OF NASA PERSONNEL INVOLVED:** 25

**ARE CONTRACTORS INVOLVED (INDUSTRIAL AND/OR ACADEMIC):**

Many of both.

**OTHER NASA CENTERS INVOLVED:** LERC - AMES - JPL

**WHAT ARE OBJECTIVES OF THE PROGRAM:**

Improve the toughness of composite materials such as fatigue, fracture, etc. Also develop processing technology for advanced composite matrix resins and material forms. Improve performance.

**WHAT ARE KEY PARAMETERS THIS RTOP IS AIMED AT IMPROVING:**

Strain to failure with induced damage and fracture behavior of composites.

**WHAT NASA SPACE OR AERONAUTICS PROGRAM IS RTOP AIMED AT:**

Application of composites to transport aircraft coupled with energy conservation projects.

**IS THIS RTOP BASIC RESEARCH OR DEVELOPMENT:**

More oriented toward advanced development.

**DO YOU SEE AN INDUSTRIAL APPLICATION FOR THE PROGRAM RESULTS:**

Yes - any polymeric system using composite materials (resin matrix)

**WHERE DO YOU THINK YOU ARE WITH RESPECT TO INDUSTRY DEVELOPMENTS:**

Ahead in understanding, even or behind in applications.

**WHAT INDUSTRIES ARE WORKING IN THIS SAME AREA:**

Any industry using materials.

**ARE THESE INDUSTRIES AHEAD OR BEHIND IN RESPECT TO WHERE YOU STAND:**

Comparable.

**WHAT IS RTOP SCHEDULE FOR GENERATION OF RESULTS (IN TERMS OF SIGNIFICANT ACCOMPLISHMENTS/MILESTONES AND WHEN):**

Target for a material strain to failure (.004). In 1988 hope for ultimate strain of .006 which is a 50% improvement in compression

**ANY OTHER INFORMATION YOU MAY WISH TO VOLUNTEER:**

QUESTIONNAIRE FOR RTOP PRINCIPALS

**NAME:** Carl Lowell (Alex Vary in charge of NDE Applications)  
(Don Buckley (X 464) in charge of tribology)

**ADDRESS:** LERC

**TEL. NO.:** 216-433-4000 X6922

**CENTER/DEPARTMENT:**

**RTOP NUMBER:** W84-70145 (506-53-12)

**RTOP TITLE:** Materials Science - NDE and Tribology

**RTOP FUNDING:** 307K

**ESTIMATED PROGRAM DURATION:** 5 years

**WHEN DID PROGRAM START:** 1983

**NUMBER OF NASA PERSONNEL INVOLVED:** 7

**ARE CONTRACTORS INVOLVED (INDUSTRIAL AND/OR ACADEMIC):** No

**OTHER NASA CENTERS INVOLVED:** No

**WHAT ARE OBJECTIVES OF THE PROGRAM:**

- o By 1986, develop non destructive evaluation technology characterizing microstructure and morphology in materials research aimed at improving properties of super alloys, composites and ceramics.
- o By end of 1987 determine feasibility of interrogating metals via NDE techniques to assess mechanical properties (fatigue, creep, ductility).

**WHAT ARE KEY PARAMETERS THIS RTOP IS AIMED AT IMPROVING:**

Supply improved techniques to evaluate design properties without destruction. This gives feed-back to metallurgists.

**WHAT NASA SPACE OR AERONAUTICS PROGRAM IS RTOP AIMED AT:**

Space in general - shuttle engines, filament cases, etc.

**IS THIS RTOP BASIC RESEARCH OR DEVELOPMENT:**

Basic

**DO YOU SEE AN INDUSTRIAL APPLICATION FOR THE PROGRAM RESULTS:**

Yes! Many! Deere for example. Any manufacturer.

**WHERE DO YOU THINK YOU ARE WITH RESPECT TO INDUSTRY DEVELOPMENTS:**

Depends on technique used. For this technique we are ahead - for others on par.

**WHAT INDUSTRIES ARE WORKING IN THIS SAME AREA:**

Most companies are interested in applications rather than developing techniques - does not see industry equivalent.

**ARE THESE INDUSTRIES AHEAD OR BEHIND IN RESPECT TO WHERE YOU STAND:**

Difficult to tell.

**WHAT IS RTOP SCHEDULE FOR GENERATION OF RESULTS (IN TERMS OF SIGNIFICANT ACCOMPLISHMENTS/MILESTONES AND WHEN):**

Determine residual life of components - time period not specified.

**ANY OTHER INFORMATION YOU MAY WISH TO VOLUNTEER:**

This RTOP is Non-Destructive Evaluation (NDE) oriented.

QUESTIONNAIRE FOR RTOP PRINCIPALS

**NAME:** Henry Lum

**ADDRESS:** AMES

**TEL. NO.:** 415-965-6544

**CENTER/DEPARTMENT:**

**RTOP NUMBER:** W84-70182 (506-54-61)

**RTOP TITLE:** Advanced Concepts for Knowledge-Based Expert Systems.

**RTOP FUNDING:** 550K

**ESTIMATED PROGRAM DURATION:** 5 years

**WHEN DID PROGRAM START:** 1983

**NUMBER OF NASA PERSONNEL INVOLVED:** 5

**ARE CONTRACTORS INVOLVED (INDUSTRIAL AND/OR ACADEMIC):**

3 Contractors + Universities + Industry

**OTHER NASA CENTERS INVOLVED:**

GSFC + JSC

**WHAT ARE OBJECTIVES OF THE PROGRAM:**

- o Develop symbolic processor hardware architecture for spaceborne systems
- o Develop languages and user-friendly interfaces
- o Develop Artificial Intelligence work stations for multi-uses

**WHAT ARE KEY PARAMETERS THIS RTOP IS AIMED AT IMPROVING:**

Generically, man's productivity using expert systems commonly referred to as "automation".

**WHAT NASA SPACE OR AERONAUTICS PROGRAM IS RTOP AIMED AT:**

Science experiments. C141 Kuyper Airborne Observatory (KAO)

**IS THIS RTOP BASIC RESEARCH OR DEVELOPMENT:**

Basic for AI

**DO YOU SEE AN INDUSTRIAL APPLICATION FOR THE PROGRAM RESULTS:**

Yes - in next year people will come to Ames to work in the AI research facility (to be built). Industrial uses will be narrow-the technology for expert systems using machine vision and later robotics.

**WHERE DO YOU THINK YOU ARE WITH RESPECT TO INDUSTRY DEVELOPMENTS:**

Ahead in these areas.

**WHAT INDUSTRIES ARE WORKING IN THIS SAME AREA:**

Digital Equipment Corp (DEC), Symbolic, SRI, Martin Marietta, Denver

**ARE THESE INDUSTRIES AHEAD OR BEHIND IN RESPECT TO WHERE YOU STAND:**

Behind - NASA is doing the high risk work

**WHAT IS RTOP SCHEDULE FOR GENERATION OF RESULTS (IN TERMS OF SIGNIFICANT ACCOMPLISHMENTS/MILESTONES AND WHEN):**

Demonstrate prototype for astrophysics mission in Nov. 1984 for astronomy mission.

**ANY OTHER INFORMATION YOU MAY WISH TO VOLUNTEER:**

Another way to describe overall objectives = look at star fields and plan scope of mission. Also classify trajectory of aircraft and time astronomer has to get information. Later on possibly identify star groups.

QUESTIONNAIRE FOR RTOP PRINCIPALS

NAME: Al. J. Meintel, Jr.

ADDRESS: LARC

TEL. NO.: 804-865-2489

CENTER/DEPARTMENT:

RTOP NUMBER: W84-70183 (506-54-63) \* See Note

RTOP TITLE: Automation Systems Research

RTOP FUNDING: 550K

ESTIMATED PROGRAM DURATION: Continuing

WHEN DID PROGRAM START: 1980

NUMBER OF NASA PERSONNEL INVOLVED: 20

ARE CONTRACTORS INVOLVED (INDUSTRIAL AND/OR ACADEMIC):

Yes - varies with time-mainly Martin Marietta, Denver Aerospace

OTHER NASA CENTERS INVOLVED:

JPL - MSFC - GSFC - JSL

WHAT ARE OBJECTIVES OF THE PROGRAM:

Systems integration to allow supervisory control of an automated remote system such as teleoperators. Also provide automated manipulation, mobility, sensing, and actuator technology. Define sensor, actuator, computer requirements and formulate and evaluate control techniques with many machine interfaces. \* See Note

WHAT ARE KEY PARAMETERS THIS RTOP IS AIMED AT IMPROVING:

Improve capability to have man operate a system without exposure to a hostile environment.

WHAT NASA SPACE OR AERONAUTICS PROGRAM IS RTOP AIMED AT:

Satellite servicing, space assembly and support of Space Station.

IS THIS RTOP BASIC RESEARCH OR DEVELOPMENT:

Basic.

**DO YOU SEE AN INDUSTRIAL APPLICATION FOR THE PROGRAM RESULTS:**

Yes - any industrial hostile environment. Also military, nuclear, mining, etc. Industrial automation especially general purpose factories like flexible machine stations.

**WHERE DO YOU THINK YOU ARE WITH RESPECT TO INDUSTRY DEVELOPMENTS:**

Depends - for teleoperators, we are even at the systems level we are ahead (combining sensors, actuators, computers, communication + man.

**WHAT INDUSTRIES ARE WORKING IN THIS SAME AREA:**

IBM, Unimation, universities - All are starting to look at the systems level.

**ARE THESE INDUSTRIES AHEAD OR BEHIND IN RESPECT TO WHERE YOU STAND:**

We are trying to establish a laboratory for computers and manipulators to do research

**WHAT IS RTOP SCHEDULE FOR GENERATION OF RESULTS (IN TERMS OF SIGNIFICANT ACCOMPLISHMENTS/MILESTONES AND WHEN):**

No date for developing a software system to simulate all above components in order to manipulate variables without changing hardware.

**ANY OTHER INFORMATION YOU MAY WISH TO VOLUNTEER:**

\*Note: This area of technology should be viewed as one RTOP called "Automation Technology Research" and broken down into 3 RTOPs:

1. 506-54-63- Automation Sensors
2. 506-57-23- Man/Machine Interface
3. 506-64-23- Systems

Due to HQ. reorganization, all RTOP's will come under Lee Holcomb.

In essence this field of technology is aimed at providing a means for gathering information and conducting work in an environment hostile to man. Man could be in a space vehicle or on the ground.

Jim Albus of NBS is also working in this field.



#5a.

SEE RTOP 506-54-66

QUESTIONNAIRE FOR RTOP PRINCIPALS

NAME: A.J. Meintel, Jr.

ADDRESS: LANGLEY

TEL. NO.: 804-865-2489

CENTER/DEPARTMENT:

RTOP NUMBER: W84-70220 (506-57-23)

RTOP TITLE: Manned Control of Remote Operations

RTOP FUNDING:

ESTIMATED PROGRAM DURATION:

WHEN DID PROGRAM START:

NUMBER OF NASA PERSONNEL INVOLVED: 3

ARE CONTRACTORS INVOLVED (INDUSTRIAL AND/OR ACADEMIC):

OTHER NASA CENTERS INVOLVED:

WHAT ARE OBJECTIVES OF THE PROGRAM:

WHAT ARE KEY PARAMETERS THIS RTOP IS AIMED AT IMPROVING:

WHAT NASA SPACE OR AERONAUTICS PROGRAM IS RTOP AIMED AT:

IS THIS RTOP BASIC RESEARCH OR DEVELOPMENT:

DO YOU SEE AN INDUSTRIAL APPLICATION FOR THE PROGRAM RESULTS:

WHERE DO YOU THINK YOU ARE WITH RESPECT TO INDUSTRY DEVELOPMENTS:

WHAT INDUSTRIES ARE WORKING IN THIS SAME AREA:

ARE THESE INDUSTRIES AHEAD OR BEHIND IN RESPECT TO WHERE YOU STAND:

WHAT IS RTOP SCHEDULE FOR GENERATION OF RESULTS (IN TERMS OF SIGNIFICANT ACCOMPLISHMENTS/MILESTONES AND WHEN):

ANY OTHER INFORMATION YOU MAY WISH TO VOLUNTEER:

QUESTIONNAIRE FOR RTOP PRINCIPALS

NAME: D. S. Friedman

ADDRESS: GODDARD

TEL. NO.: 301-344-6242

CENTER/DEPARTMENT:

RTOP NUMBER: W84-70185 (506-54-66)

RTOP TITLE: Automation Machine Intelligence, Automated Planning, Scheduling and Control

RTOP FUNDING: 390K

ESTIMATED PROGRAM DURATION:

WHEN DID PROGRAM START:

NUMBER OF NASA PERSONNEL INVOLVED:

3.5 At this time this RTOP has been zeroed out in FY 1985. 3 investigators: left NASA; 1 on assignment to space station at JSC; i now reviewing SRIR documents full-time. per Friedman

ARE CONTRACTORS INVOLVED (INDUSTRIAL AND/OR ACADEMIC):

OTHER NASA CENTERS INVOLVED:

WHAT ARE OBJECTIVES OF THE PROGRAM: Many tasks -

A. Demonstrate applicability of expert system technology in a spacecraft control center development. Results would be an automated ground control center which would support detailed study of how automation effects

WHAT ARE KEY PARAMETERS THIS RTOP IS AIMED AT IMPROVING:

Command control 1 analysis function

WHAT NASA SPACE OR AERONAUTICS PROGRAM IS RTOP AIMED AT:

IS THIS RTOP BASIC RESEARCH OR DEVELOPMENT:

DO YOU SEE AN INDUSTRIAL APPLICATION FOR THE PROGRAM RESULTS:

WHERE DO YOU THINK YOU ARE WITH RESPECT TO INDUSTRY DEVELOPMENTS:

WHAT INDUSTRIES ARE WORKING IN THIS SAME AREA:

B. Machine intelligence (basic research) in MI, primarily at universities to develop long range relationship at major universities

ARE THESE INDUSTRIES AHEAD OR BEHIND IN RESPECT TO WHERE YOU STAND:

WHAT IS RTOP SCHEDULE FOR GENERATION OF RESULTS (IN TERMS OF SIGNIFICANT ACCOMPLISHMENTS/MILESTONES AND WHEN):

ANY OTHER INFORMATION YOU MAY WISH TO VOLUNTEER:

QUESTIONNAIRE FOR RTOP PRINCIPALS

**NAME:** Henry W. Brandhorst Jr. - On vacation, talked to Dennis Flood X6303

**ADDRESS:** LERC

**TEL. NO.:** 216-443-4000 X786

**CENTER/DEPARTMENT:**

**RTOP NUMBER:** W84-70191 (506-55-42)

**RTOP TITLE:** Photovoltaic Energy Conversion

**RTOP FUNDING:** 1775K

**ESTIMATED PROGRAM DURATION:** R&D Continuing

**WHEN DID PROGRAM START:** Early Sixties

**NUMBER OF NASA PERSONNEL INVOLVED:** 30

**ARE CONTRACTORS INVOLVED (INDUSTRIAL AND/OR ACADEMIC):**

University Grants + Hughes, Varian, etc.

**OTHER NASA CENTERS INVOLVED:**

JPL - LARC - GSFC - MSFC

**WHAT ARE OBJECTIVES OF THE PROGRAM:**

Improve efficiency, reduce costs, reduce mass improve life of photovoltaic power generators for space applications. Concentrating on gallium/arsenide arrays.

**WHAT ARE KEY PARAMETERS THIS RTOP IS AIMED AT IMPROVING:**

Specific power (power to mass ratio) for photovoltaic solar arrays.

**WHAT NASA SPACE OR AERONAUTICS PROGRAM IS RTOP AIMED AT:**

Space Station.

**IS THIS RTOP BASIC RESEARCH OR DEVELOPMENT:**

Both - Basic for fundamental materials properties and solar cell physics;  
Development for developing a system

**DO YOU SEE AN INDUSTRIAL APPLICATION FOR THE PROGRAM RESULTS:**

Yes - but all for space applications. Industry interested in gallium/arsenide cell development and cell design.

DOE interested in a stand-alone system for about 2 to 10 Kw

**WHERE DO YOU THINK YOU ARE WITH RESPECT TO INDUSTRY DEVELOPMENTS:**

Industry is very conservative so they do not work in this area except for space applications.

**WHAT INDUSTRIES ARE WORKING IN THIS SAME AREA:**

**ARE THESE INDUSTRIES AHEAD OR BEHIND IN RESPECT TO WHERE YOU STAND:**

**WHAT IS RTOP SCHEDULE FOR GENERATION OF RESULTS (IN TERMS OF SIGNIFICANT ACCOMPLISHMENTS/MILESTONES AND WHEN):**

Concentrator cell of 22% efficiency at 100 suns at 85°C. This equates to 25% terrestrial efficiency (magic number everyone aims at)

**ANY OTHER INFORMATION YOU MAY WISH TO VOLUNTEER:**

- o Major problem for industry is cost/effectiveness.
- o Spin off of work in lasers may help in field of microelectronics.
- o Oil company's are also interested, but for different applications. (did not have any details on this)

QUESTIONNAIRE FOR RTOP PRINCIPALS

**NAME:** M. Ralph Carruth Jr.

**ADDRESS:** MSFC

**TEL. NO.:** 205-453-4275

**CENTER/DEPARTMENT:**

**RTOP NUMBER:** W84-70194 (506-55-48)

**RTOP TITLE:** Multi-KW Concentrator Solar Array - Space Station Augmentation

**RTOP FUNDING:** 116K

**ESTIMATED PROGRAM DURATION:** 1987

**WHEN DID PROGRAM START:** 1984

**NUMBER OF NASA PERSONNEL INVOLVED:** 3

**ARE CONTRACTORS INVOLVED (INDUSTRIAL AND/OR ACADEMIC):**

Industry (TRW) + (ASTRO Research Corp.)

**OTHER NASA CENTERS INVOLVED:** No

**WHAT ARE OBJECTIVES OF THE PROGRAM:**

1. Apply past work to expand into a solar array for space station power.
2. Develop a CASSAGRANIAN concentrator solar array-approximately 10 KW--each but can be connected to large arrays in a modularized fashion.

**WHAT ARE KEY PARAMETERS THIS RTOP IS AIMED AT IMPROVING:**

Panel and wing level design. Increase efficiency of solar array and lower cost.

**WHAT NASA SPACE OR AERONAUTICS PROGRAM IS RTOP AIMED AT:**

Space Station.

**IS THIS RTOP BASIC RESEARCH OR DEVELOPMENT:**

Development.

DO YOU SEE AN INDUSTRIAL APPLICATION FOR THE PROGRAM RESULTS:

Does not see any.

WHERE DO YOU THINK YOU ARE WITH RESPECT TO INDUSTRY DEVELOPMENTS:

Industry is under contract to NASA and therefore they are about even.

WHAT INDUSTRIES ARE WORKING IN THIS SAME AREA:

ARE THESE INDUSTRIES AHEAD OR BEHIND IN RESPECT TO WHERE YOU STAND:

WHAT IS RTOP SCHEDULE FOR GENERATION OF RESULTS (IN TERMS OF SIGNIFICANT ACCOMPLISHMENTS/MILESTONES AND WHEN):

End of FY 87 have technology ready to use on a modular array.

ANY OTHER INFORMATION YOU MAY WISH TO VOLUNTEER:

Last minute note: called me back to tell me HQ intends to drop this RTOP next year!



QUESTIONNAIRE FOR RTOP PRINCIPALS

**NAME:** Larry H. Thaller

**ADDRESS:** LERC

**TEL. NO.:** 216-433-4000 ext. 5260

**CENTER/DEPARTMENT:**

**RTOP NUMBER:** W84-70196 (56-55-42)

**RTOP TITLE:** Electro Chemical Energy Conversion and Storage

**RTOP FUNDING:** 1121 K

**ESTIMATED PROGRAM DURATION:** R & D Continuing

**WHEN DID PROGRAM START:** "Long time"?

**NUMBER OF NASA PERSONNEL INVOLVED:** 25

**ARE CONTRACTORS INVOLVED (INDUSTRIAL AND/OR ACADEMIC):** Yes - Universities and Hardware Contractors e.g., United Technologies Corporation

**OTHER NASA CENTERS INVOLVED:** JSC

**WHAT ARE OBJECTIVES OF THE PROGRAM:** Verify large energy storage systems at high power approximately 50 kw (100-200 volts). Investigate use of nickel/hydrogen systems in low earth orbit to replace nickel/cadmium batteries

**WHAT ARE KEY PARAMETERS THIS RTOP IS AIMED AT IMPROVING:** Develop credible data base for fuel cells and electrolytes.

**WHAT NASA SPACE OR AERONAUTICS PROGRAM IS RTOP AIMED AT:** Space Station

**IS THIS RTOP BASIC RESEARCH OR DEVELOPMENT:** Development

DO YOU SEE AN INDUSTRIAL APPLICATION FOR THE PROGRAM RESULTS: No!  
Nickel/hydrogen cells too expensive no terrestrial applications for hydrogen/oxygen fuel cells. Industry uses acid electrolytes.

WHERE DO YOU THINK YOU ARE WITH RESPECT TO INDUSTRY DEVELOPMENTS:  
Not Involved

WHAT INDUSTRIES AHEAD OR BEHIND IN RESPECT TO WHERE YOU STAND:

WHAT IS RTOP SCHEDULE FOR GENERATION OF RESULTS (IN TERMS OF SIGNIFICANT ACCOMPLISHMENTS/MILESTONES AND WHEN): Acceptance of this concept in about 2 years as the energy storage system for the space station.

ANY OTHER INFORMATION YOU MAY WISH TO VOLUNTEER:

QUESTIONNAIRE FOR RTOP PRINCIPALS

NAME: Irving Stein

ADDRESS: JPL

TEL. NO.: 213-354-6048

CENTER/DEPARTMENT:

RTOP NUMBER: W84-70198 (506-55-55)

RTOP TITLE: Advanced Electrochemical Systems

RTOP FUNDING: 1216K

ESTIMATED PROGRAM DURATION: 1990

WHEN DID PROGRAM START: 1979

NUMBER OF NASA PERSONNEL INVOLVED: 8

ARE CONTRACTORS INVOLVED (INDUSTRIAL AND/OR ACADEMIC): No

OTHER NASA CENTERS INVOLVED: No

**WHAT ARE OBJECTIVES OF THE PROGRAM:**

1. Look at new ideas - feasibility of various components for high energy density cells, e.g., polymeric components
2. Primary lithium batteries - 300/watts/hr/kg - 5 year life
3. Secondary lithium batteries - 100/watts/hr/kg - 10 year life

**WHAT ARE KEY PARAMETERS THIS RTOP IS AIMED AT IMPROVING:**

Energy density, life, safety, reliability, high rate

**WHAT NASA SPACE OR AERONAUTICS PROGRAM IS RTOP AIMED AT:**

Planetary missions, probes, Space Station, geosynchronous orbits, Shuttle

**IS THIS RTOP BASIC RESEARCH OR DEVELOPMENT:**

Primary batteries = development

Secondary batteries and feasibility studies = basic

**DO YOU SEE AN INDUSTRIAL APPLICATION FOR THE PROGRAM RESULTS:**

Yes! replace nickel/cadmium batteries - smaller, lighter = 5 x energy of same size. Replace silver/zinc batteries now used in aircraft starting, etc.

**WHERE DO YOU THINK YOU ARE WITH RESPECT TO INDUSTRY DEVELOPMENTS:**

for lithium batteries, industry is moving ahead. Basic understanding and safety - NASA ahead

**WHAT INDUSTRIES AHEAD OR BEHIND IN RESPECT TO WHERE YOU STAND:**

**WHAT IS RTOP SCHEDULE FOR GENERATION OF RESULTS (IN TERMS OF SIGNIFICANT ACCOMPLISHMENTS/MILESTONES AND WHEN):**

End of FY 1984, deliver an engineering model of a primary lithium cell "D" size (lithium/thionyl/chloride)

**ANY OTHER INFORMATION YOU MAY WISH TO VOLUNTEER:**

Emphasis is on making batteries safer and cheaper, but NASA does not press "cheaper" - industry should

QUESTIONNAIRE FOR RTOP PRINCIPALS

**NAME:** Edmond J. Conway

**ADDRESS:** LARC

**TEL. NO.:** 804-865-3781

**CENTER/DEPARTMENT:**

**RTOP NUMBER:** W84-70204 (506-55-73)

**RTOP TITLE:** Advanced Space Power Conversion Distribution

**RTOP FUNDING:** 1027M

**ESTIMATED PROGRAM DURATION:** Long Range R&D - Continuing

**WHEN DID PROGRAM START:** 1983 in current form

**NUMBER OF NASA PERSONNEL INVOLVED:** 30

**ARE CONTRACTORS INVOLVED (INDUSTRIAL AND/OR ACADEMIC):**

Industry = Small

University = Colorado, Florida, Old Dominion, Miami of Ohio, and Others

**OTHER NASA CENTERS INVOLVED:** JPL & MSFC

**WHAT ARE OBJECTIVES OF THE PROGRAM:**

Develop a laser space power transmission system to provide capability to get power from a space generator to spacecraft. Range of 100 kw minimum to about 10 megawatts. Develop efficient conversion to electric power.

**WHAT ARE KEY PARAMETERS THIS RTOP IS AIMED AT IMPROVING:**

R&D to explore feasibility of this concept currently looking at nuclear pumped lasers - would like to explore solar pumped lasers. Question is - can it be done?

**WHAT NASA SPACE OR AERONAUTICS PROGRAM IS RTOP AIMED AT:**

All space programs

**IS THIS RTOP BASIC RESEARCH OR DEVELOPMENT:**

Basic

**DO YOU SEE AN INDUSTRIAL APPLICATION FOR THE PROGRAM RESULTS;**

Mostly in space commercialization. Potential to supply large amounts of power. Some applications may fall out from laser technology.

**WHERE DO YOU THINK YOU ARE WITH RESPECT TO INDUSTRY DEVELOPMENTS;**

Industry not working in this area.

**WHAT INDUSTRIES AHEAD OR BEHIND IN RESPECT TO WHERE YOU STAND;**

**WHAT IS RTOP SCHEDULE FOR GENERATION OF RESULTS (IN TERMS OF SIGNIFICANT ACCOMPLISHMENTS/MILESTONES AND WHEN):** Aiming for 100 watt system in 1986 using solar simulators u XENON ARC lamps which give approximately 40 kw of radiated power

**ANY OTHER INFORMATION YOU MAY WISH TO VOLUNTEER;** VORTEK Industries - Canada Filtered Merc. Xenon Works pretty well - 6/84

QUESTIONNAIRE FOR RTOP PRINCIPALS

**NAME:** Louis W. Slifer (retired) Floyd Ford x 5845 in charge talked to Mike Tasevoli

**ADDRESS:** GSFC

**TEL. NO.:** 301-344-8841

**CENTER/DEPARTMENT:**

**RTOP NUMBER:** W84-70206 (506-55-76)

**RTOP TITLE:** Advanced Power System Technology

**RTOP FUNDING:** 350K

**ESTIMATED PROGRAM DURATION:** 1989

**WHEN DID PROGRAM START:** 1980

**NUMBER OF NASA PERSONNEL INVOLVED:** 7

**ARE CONTRACTORS INVOLVED (INDUSTRIAL AND/OR ACADEMIC):** Lockheed

**OTHER NASA CENTERS INVOLVED:** No

**WHAT ARE OBJECTIVES OF THE PROGRAM:**

1. Overall survey of advances in industry (batteries, solar arrays and power electronics)
2. Analyze modelling of power sub-system designs and develop models to predict DC & AC stability performance.
3. Overall - advance knowledge and understanding of power system technologies.

**WHAT ARE KEY PARAMETERS THIS RTOP IS AIMED AT IMPROVING:**

System design of a power sub-system from the component level up.

**WHAT NASA SPACE OR AERONAUTICS PROGRAM IS RTOP AIMED AT:**

All future missions e.g., UARS (Upper Atmosphere Research Satellite)

**IS THIS RTOP BASIC RESEARCH OR DEVELOPMENT:**

Development

**DO YOU SEE AN INDUSTRIAL APPLICATION FOR THE PROGRAM RESULTS:**  
Not apparent from today's information

**WHERE DO YOU THINK YOU ARE WITH RESPECT TO INDUSTRY DEVELOPMENTS:** Most work in industry is in support of NASA.

**WHAT INDUSTRIES AHEAD OR BEHIND IN RESPECT TO WHERE YOU STAND:**

**WHAT IS RTOP SCHEDULE FOR GENERATION OF RESULTS (IN TERMS OF SIGNIFICANT ACCOMPLISHMENTS/MILESTONES AND WHEN):** Complete power sub-system model 1988. Use of a flywheel as an energy storage system - 1987 prototype.

**ANY OTHER INFORMATION YOU MAY WISH TO VOLUNTEER:**



APPENDIX C

TRIP REPORT

## APPENDIX C

### TRIP REPORT

DATE: August 10, 1984  
BY: Tom Ross, Lou Mogavero, Peter Castruccio  
TO: Langley Research Center, Hampton, VA. Accompanied during office visits by Mr. John Samos, Technology Utilization Officer, and also by Lester Rose, Deputy Technology Officer, during lunch.

1. Visit to the Office of Alfred J. Meintel and Jack Pennington.

Subject: Automation Technology Research

The discussion covered all of this branch's activities in automation systems research and remote operations in space. These are covered by four RTOPS. Recently, the interest of the branch broadened to include space station, specifically, two systems: EVA (Extra-Vehicular Activity) and RMS (Remote Manipulator System).

The NASA system philosophy is that NASA is mainly interested in operator-driven systems. The operator could be located anywhere, including on Earth.

Activities include all systems technologies associated with Remote Manipulation, e.g., communications, sensing, display, bandwidth. The same technology is applicable to nuclear power plants (being currently studied by Oak Ridge) and underwater repairs, etc., being currently studied by the Navy Ocean Systems Command, Pacific.

Additionally, the Bureau of Mines has expressed interest in this technology for purposes of mining.

Meintel emphasized that teleoperation must be considered as a complete system. This also includes force and torque sensors and computers, micro-processors in fingers and wrists, optical and ultrasonic proximity sensing (the latter not usable in space).

The approach of man-machine remote operation is called "telepresence" by Marvin Minsky of M.I.T. The key idea is to make the man think naturally, i.e., be exposed to "natural" stimuli, capable of making him consider himself "transposed" to the work area.

As the degree of automation grows, man may give up some tactile and other stimuli, in favor of increasing operation in a "supervisory" mode. Meintel indicated they do not currently think beyond 20 years to what may eventually become fully self-contained robotics.

Meintel's systematic approach to automation technology (AT) hinges upon 3 major points:

1. Structure in the system
2. Identify technological gaps and fix them (evolving)
3. Effectively get man to operate in the system

As regards the state-of-the-art, Meintel indicated:

1. Teleoperator is here now
2. Directed control, i.e., partial closures of the loop by certain sensors, can be accomplished in approximately 10 years. Critical in this respect is the delay between transmission and reception by the man. Critical threshold for man to use continuous control is a time delay of from .15 to .25 seconds. Longer delays require a "move and wait" mode of operation. Delay is high in space applications because of relaying from TDRS. No problem on the ground except for long distances underwater. Space and industrial applications differ. Industry needs fast, repetitive, automated operations; however, for space applications, NASA most frequently uses once-in-a-while operation. This is why current ground operations do not use man in the loop. Another reason is that hydraulic controls, used on the

ground, are stiff, thus require fast reaction. In space, most controls are electrical and speed is not critical.

3. Supervisory control. This includes more intelligence in the system, however, man will still be in the loop. Meintel thinks this stage will be begun in 1995 to 2000.

LRC is currently moving into step 2 above.

Current industrial manipulators have precision, but not accuracy. This means that they can be reset at any preset place with high accuracy; do not have the same accuracy when commanded to move to a specific place without prior setting. Good repeatability, poor positioning.

There is considerable interest in industry's part in solving this problem. The problem is very much less severe when man is in the loop. Big need is for an active sensor to close the control loop, i.e., a sensor to accurately define position in presumably three dimensions.

Working on the problem is Jim Albus of NBS (National Bureau of Standards).

Industry is not working on teleoperations (TO), except in the case of hazardous environments; e.g., nuclear energy and mining or underwater applications.

Meintel is establishing a data-base of tests of accuracy and performance parameters of TO.

No work is being done on "bionics".

Key techniques they are working at in the laboratory are: simulation; conversion of tactile information into visual information; 3-D TV. The audio pattern recognition effort has been abandoned, because it is currently being pursued by universities.

### Preliminary conclusions

1. Although the research being done at Langley is basic to both industry and NASA, the ultimate applications differ. Industry aims at getting the man out of the loop; Langley's work is aimed at maintaining man in the loop for space operations.
2. However, this research could be very valuable for terrestrial operations in hostile environments. (Military, nuclear, fire fighting, underwater, mining, etc.)
3. Therefore, industries to be focused on should fall into this latter category.
4. Companies such as IBM, Unimation, the communications industry, and universities are looking at the systems approach to teleoperations.
5. This means that two industrial focus points ought to be investigated: a) potential users; b) current researchers on the same subject.

Meintel indicates that:

1. LRC is ahead of industry in the systems approach;
2. LRC is even with industry in the development hardware.

2. Visit to the Office of Louis F. Vosteen, Chief, Materials Division; Bland A. Stein, Head, Advanced Materials Branch; and Bob Baucom.

Subject: Advanced Composites

These materials are composed of fibers imbedded in resins. They are interleaved in different directions to obtain optimum properties. They can also be made in blocks using chopped fibers; continuous rods; filament wound; and laminated layups.

The main fibers discussed were graphite, Kevlar, glass. LRC uses primarily graphite.

Civilian industry uses primarily Kevlar, and glass.

Principal problem is that composite materials can obtain great unidirectional strength, but not polydirectional. Yet many aircraft structures are stressed in different directions. Hence, material must be carefully designed. (Often conservatively).

Composites are made so as to achieve optimum compromise of strength, weight and other properties. They can improve stiffness more than strength. Current strengths are of the same order of best available for metals. However their strength to weight ratio is higher. Densities of composites is approximately 0.65 that of aluminum.

LRC's primary focus on composites at this time is to replace aluminum in aerospace structures.

Current costs of composites are: up to \$50 per pound for the raw material; between \$100-150 per pound for in place material. A one pound saving during design may be worth up to \$200 to the aerospace industry. Cost of current aluminum structures in place is between \$100-150 per pound.

The ability to produce complex shapes with composites is better than with metals.

No composite aircraft has as yet been certified; however, a prototype plane has been built and successfully flown by Lear. We are on the threshold of all-composite aircraft.

Although composites are much easier to cast, because that just requires molding, they are more difficult to machine than metals. Require diamond saws, special drills, etc.

Interlaminar fracture is a primary concern. This is because currently used resins have only 15-20 thousand psi tensile of strength in non-reinforced axis. Thus design must be sophisticated. Industry addresses this problem constantly. Need "tougher" resins.

Fiber comes in continuous extrusions. Diameter is approximately 6 microns, so packaged in bundles of 3,000, 6,000 or larger number of fibers. This bundle is called a tow.

The next subject verged on potential users.

Industry uses composites wherever they need good stiffness-to-strength and stiffness-to-density. Examples are machinery that continuously stops and starts, e.g. weaving shuttles, reciprocating parts, inertial wheels. Polymotor in New Jersey built a composite engine on a \$2 million contract for Ford. Four cycle reciprocating, probably 1600 cc. Composites are used in the block, rods, pistons (except top layer of aluminum), heads, etc. Kevlar fibers are used in Aramid tires, and these are made in great quantities. There is now a trend to using Kevlar in brake shoes. In fact, Kevlar fibers currently outsell graphite fibers by approximately 10 to 1.

Major problem is economics. There is a small production U.S. wide of graphite fibers. This causes high costs. Total U.S. production of graphite fibers is approximately 3 million pounds per year.

Principal graphite fiber suppliers: Hercules; Union Carbide; Celanese; DuPont; Courtaulds, U.K.; Toray, Japan.

Silicon carbide fibers are good for high temperature applications.

Kevlar is used extensively in woven fabrics. For example, in addition to tires, bullet-proof vests are made of Kevlar, as well as U.S. Army helmets.

Composites have good properties in fatigue, if not wrongly stressed. Sometimes internal damage can be caused by shock or impact, and this can be hard to detect (unlike bent aluminum). Best current method of damage detection is ultrasonic.

The capital investment and labor intensiveness of making composites makes them relatively expensive compared to aluminum.

Advantage of composites: In aerospace applications, parts can be fabricated in large monolithic structures. Advantages of this are:

- o Part count is lower; paper work is thereby reduced and inventory reduced; results in lower costs
- o Fasteners are eliminated or greatly reduced. Aerospace fasteners are very costly
- o Operational costs are lowered; lighter weight causes less energy expense
- o Maintenance costs are lower, mostly from lower amount of corrosion. Example cited where extensive corrosion found under galleys and toilets in large aircraft.

New trends are for Tough Composites. This requires additional research on resins. Resins are a key area. Thermoplastics are being tried and are good, but sensitive to corrosion (from paint, solvents, etc.). Trade-offs will be required.

Although the market is relatively small, innovative applications have been made in prosthetic devices such as hip joint replacements and braces.

Bland Stein will send written reports. (Received Aug. 16, 1984)



### Preliminary Conclusions on Advanced Composites

1. We should contact one major aerospace company, e.g., Boeing with the questions of whether the Langley group is more or less advanced with respect to what Boeing is now doing in composite aerospace materials, particularly graphite composites.
  2. If answer from Boeing is negative or indifferent, there would still be a niche to be explored for the Langley technology in the smaller industries making reciprocating or highly stressed parts, e.g., weavers shuttles, engines, rotating machinery, etc.
  3. One of the major producers of graphite fibers, such as Union Carbide, should be contacted to determine their interests and applications for NASA research.
3. Visit to the Office of Edward J. Conway

Subject: Advanced Space Power Conversion and Distribution

Ed is working exclusively for space applications. Principal endeavor is the generation of power and its conveyance at a distance from space craft to space craft. Concept is a power-generating platform which would supply other space craft at a distance.

The technical approach is solar energy conversion through lasers and conveyance of energy through laser beams. LRC is working on both the transmitting and the receiving ends.

Laser Systems being investigated:

1. Solar pumped/gas lasers

They are working with different materials for laser. A promising one is  $C_3F_7I$ . This is a liquid compound, which disassociates under the application of solar energy into  $C_3F_7$  and excited iodine. The lasing iodine (I) is excited at 2,700-2,900 Å (Angstroms). Conversion efficiency is 0.1%. Laser output is at 1.3 microns. Lasing currently lasts for periods up to 1 second. Peak output is 1-10 watt for 0.5 seconds. The goal is 100 watts by the end of 1985. Device needs gas flow.

Device is not usable on earth because of absence of UV (ultra-violet).

Solar concentration ratio used so far is 10 thousand solar constants. This is accomplished by a precision mirror. Expected in the near future to improve to only about 200 solar constants, using a laser length of 60 centimeters. This can be accomplished by a parabolic trough, using high quality surface to reflect the UV.

2. I Br laser. This lases at 4,000-5,500 Å. So far they have obtained a 300 watt output using simulated sunlight with flash lamp pump. Pulse of 100 microseconds. Material must flow at supersonic speeds to avoid quenching of iodine by disassociated free bromide.

This material was found too difficult to work with, thus effort was terminated.

3. Liquid laser using neodymium. Output is 1.06 microns. Developed initially by Sylvania. A good potential for solar-pump lasing. Currently requires 10 thousand solar constants. Expected to operate at 900 solar constants, if lasing tube is made 18 inches long. Liquid is highly corrosive and has explosive potential when mixed with water. Conversion efficiency is approximately 1%. When doped with chromium, possible total efficiency rises to 10% over total solar spectrum.

This work is being done under grant by University of Florida.

4. Heat Laser. This is a simple, gas dynamics black body pump laser whose thermal radiation, from cavity to laser, excites lasing. Efficiency is of order .5 to 1%. This is internal efficiency, i.e., from cavity to laser.

C-2

External efficiency, i.e., solar to cavity, is expected to be 0.5%. Therefore, total efficiency should range from 0.25 to 0.5%.

The black body radiation heats  $N_2$ . When  $N_2$  is mixed with  $CO_2$ ,  $N_2$  transfers energy to  $CO_2$ , which lases. The entire device is approximately 2 cubic feet.

Receivers being investigated:

1. Laser-MHD (Magneto-hydrodynamic). These have produced small powers. The laser ionizes a gas which is then converted to energy through standard MHD. The difference is that in industrial MHD generation the container walls are warmed. In this device the walls are cooler, and the gas itself is heated by the laser radiation.
2. Laser Photovoltaic. This is a solar cell for conversion of laser energy. Can be as high as 50% efficient within the tuned laser band. Problem is that laser band is very narrow, thus this cell is probably not suited for total conversion of the solar spectrum. This is to be found out.
3. High current switch. This is a gas, externally triggered, automatically (reflectively) turned-off (perhaps turned on) switch to handle megacurrents. Typical characteristics: PRF 1,000 cycles; pulse length tens of microseconds; switching power minimum 1 mega-amp up to tens of mega-amps. Fits in a 20 X 20X 10 centimeter space. Hold-off voltage is from 100 kilovolts down to 10 kilovolts. The French are interested in this device for using CERN.

General:

Space solar cells are more expensive than terrestrial cells because potential damage from particles forces them to be monocrystalline. Additionally, quality control is expensive because of need for high reliability.

Ed's concept of the power station in space is for it to generate 1 megawatt at ranges of up to 30,000 kilometers from space craft to be resupplied.

Ed will send literature in a few days. Telephone number 804-865-3781.

Preliminary Conclusions on Space Power Conversion and Distribution

1. The efforts in laser generation and reception appear to be entirely suitable only to space uses.
2. Of interest is the high current switch. If it performs as indicated, it would apply to all utility power/generation switches, switches for cyclotrons and synchtrons, and any other very high current application.

APPENDIX D

TRIP REPORT

## APPENDIX D

### TRIP REPORT

DATE: August 24, 1984, Lewis Research Center, Cleveland, Ohio.  
BY: Peter Castruccio, Lou Mogavero, Tom Ross  
TO: Lewis Research Center, Cleveland, Ohio. Accompanied during visit by Mr. Bill Waters of the Technology Utilization Office, Lewis Research Center, at which office all discussions were held.

1. Discussing with Alex Vary, Non-Destructive Evaluation (NDE)

Subject: Materials Science - NDE contains the fields of NDT (Non-Destructive Tests) and NDI (Non-Destructive Inspection) as a part of the overall field of Materials Science.

NDE, as currently practiced, is aimed at detecting flaws. However, the NASA program is aimed at developing NDE tools which do more than just detect flaws; e.g., determine certain important mechanical characteristics of the material. At the moment, NDE is not sufficiently advanced to fully detect all physical properties, but concentrates on mechanical; e.g., detection of cracks, but not of stress-strain relationships. In using NDE, it is important to know both the characteristics of the flaw and those of the material.

There exists an arsenal of techniques for NDE. The idea is to assess micro-structure, micro-morphology, and select those items which control the mechanical properties of the material.

Ultrasonics is a prime tool for NDE, because it introduces mechanical waves. Mechanical waves appear to be the right thing to measure mechanical defects.

In using ultrasonics, it is necessary to couple the exciting device with the test

piece. To accomplish this in certain applications, they use a water tank where the test piece is submerged. Reason being that the water acts as the coupler between the transducer and the test piece, and it makes the moving of the exciter/detector easier than if one had to change or re-establish the coupling everytime the piece or transducer is moved.

The interest is in picking up variations in properties in addition to picking up flaws. In addition to assessing the characteristics of the flaw, they like to know the characteristics of the metal to understand what generated the flaw in the first place.

Another advantage of the water emergent tank is that the transducer can be scanned across the piece and the returning signals can be used to image the flaws.

The next important technique for NDE is radiography. Ultrasonics and radiography are complementary: one sees what the other misses.

The bottom line of NDE is the interpretation of the results in a qualitative fashion. The problem is to catalog the various types of flaws for the multitudiness materials. One method is to simulate defects. For example, a method used in composites is to put a mylar insert between layers. However, this is a simulation and not always can it represent the real flaw. (One reason to do this is to calibrate the NDE instrumentation).

The ultimate usages of NDE are: a) verify the techniques; b) inspection under actual conditions; c) predict the occurrence of failures.

Important in NDE is the establishment of correlations between real defects (or changes in structure) and observed test "images".

It is more important to identify a non-existing defect than to miss an existing defect.

Gross flaws are easy to detect; more difficult and important is the detection of microdefects. For example, these tiny flaws often occur in ceramic materials. The problem is whether or not one should look at all of the small defects. This is costly. An ultimate method is to inspect areas or clusters of defects in specific points of

importance; e.g., high stress areas. This technique looks at the "net effect" of the population of microflaws upon performance. What NASA is trying to do is to distinguish "good" from "bad" micro-structures, in order to rank the materials as to presence of defects and correlate findings with test results.

After the materials have been used for a while, it is important to predict the residual life. For example, fatigue degradation of composites has been predictable via NDE.

There is a large NDE effort ongoing on turbine disks for jet engines. This is sponsored by USAF Wright-Patterson Air Force Base Materials Lab. This involves approximately 20 companies. The effort is called "Retirement for Cause". What happened is that the USAF retires turban disks after a certain service time, whether they are defective or not. This new program aims at safely retiring the disks later, or reusing those already retired, which turn out not to be defective after inspection using special NDE techniques.

In this "Retirement for Cause" program, ultrasonics and eddy current techniques are used through robotic arms. The eddy current detector is a small probe with a coil, excited at a few KHz, sometimes in multiple frequencies, to measure the inductance coupling of the combination coil and material. Using both NDE systems, cracks in the metal turbine disks can be detected, evaluated, and the disks ultimate failure predicted.

In ultrasonics, most industries work between 1 and 25 megahertz. Lewis currently uses ultrasonics up to 100 megahertz. The transducers are conventional off-the-shelf or slightly modified from existing devices. This probes microstructures to around 5 to 8 microns. This can now be accomplished on practically-sized laboratory samples. What is measured are microstructural variations controlling toughness. Typical metals tested are nickel steels and tungsten carbides. Technique appears possible to adapt for application in the field, especially for testing the tungsten carbides. "Toughness" is the ability of materials to resist failure under cracks. In other words, the ability to tolerate a crack without undergoing catastrophic failure. It is measured in pounds per square inch. NDE measures the critical size of the maximum crack which can be tolerated prior to failure.



Some applications and/or materials can be found that tolerate larger cracks; some can only tolerate very small cracks, before catastrophic failure would be expected.

The National Materials Advisory Board published in 1975 a report "Rapid Inexpensive Ways to Measure Materials Toughness". Available from (NRC) National Research Council.

While tensile and yield strengths are well understood, toughness is still poorly understood. This is why Lewis now concentrates on this important property.

Dr. Heyman of Langley Research Center uses another ultrasonic technique in which he measures wave velocities to a precision of  $10^{-7}$ . He does this to measure elastic constants of the material. Lewis, on the other hand, measures ultrasonic attenuation. Langley performs its materials measurements under stress; Lewis under a relaxed unstressed state.

A possible future result of the Lewis method is the eventual ability to predict what will happen during use from knowledge of the present character of the material.

Industrial applications. No manufacturer at present guarantees toughness. It would be desirable for industrial materials manufacturers to do so. For example, sheet metal steel fabricators.

An example sighted was that of Riegel Tube Company. They make metal highway guard rails. For one job, they had to guarantee toughness for the State of New York. They "bought" the Lewis method using ultrasonics. This gave better results than the ordinarily used drop test.

United Technology Research Center in East Hartford, CT., is now researching the same types of NDE techniques. They are having discussions with Lewis people. Smith Tools International also has an application. (Proprietary). Virginia Polytechnic Institute is doing work on composites that is supported by Lewis. VPI has a grant to study composite fatigue and graphite epoxy. MIT also does supported work that is primarily in ceramics.

The principal problem of commercializing the Lewis technique of ultrasonics NDE is one of costs. The equipment is expensive. The heart of the system is a waveform digitizer (basically an A/D converter), which digitizes high frequency signals. However, Alex Vary feels these techniques can probably be made field/operational in approximately 5 years. The system now uses a PDP 11/35 with 280K. Vary considers his system to be unique in its field. The probes are off-the-shelf. However, the digital processing system appears to cost around \$200K. He has inquiries from England, Germany, Israel, India and Japan.

A conference will be held November 13 and 14, 1984 at Lewis sponsored by NASA and the ASME: "Analytical Ultrasonics Conference". NASA contact is Alex Vary.

#### Preliminary Conclusions on Non-Destructive Evaluation (NDE)

1. This technology is in significant demand.
2. There appears to be significant industrial interest.
3. The main problem to hinder commercialization of the technology is the high cost.
4. Of particular interest appears to be the area of material "toughness", which appears to be an area in materials science just emerging.

2. Discussion with Don Buckley.

Subject: Materials Science - Tribology

Don Buckley is willing to go and "sell" industry on his technology. He feels the (tribology) could be self-supporting. Does not have NASA permission. Interested companies he mentioned are IBM, IBM San Jose, IBM Tucson, Boeing, Exxon (New Jersey), Carborundum. He would like to see much more NASA/Industry cooperative work.

This branch, because of the NASA reorganization, is being transferred to the Materials Division, and it will be called " Surface Science". The interests of the laboratory are four: adhesion, friction, wear, lubrication. The overall interest is to investigate what basic material properties control these parameters.

Examples:

GE is looking for seals between glass and metal or glass and ceramics for lightbulbs. Adhesions.

Norton, "Abex" companies want high friction, low wear material for automobile brakes and clutches. They indicated that this is a "black art" (trial and error).

Low friction is needed throughout NASA aerospace efforts for bearings, gears, etc. Lubrication.

Abrasive wear is needed in machining; for example, silicon carbide wheels for grinders.

Cavitation and erosion are problems in hydraulic systems; must study and characterize.

Sealing is a problem in oil hydraulics. The laboratory does much work in lubrication, both liquids and solids. Potentially, also, NASA can contribute research in high temperature lubricants. Current industrial technique is to use fluid lubricants, plus additives, for high temperature uses. The additives reduce wear, oxidation, foaming, etc. For example, automobile oil has between 6 and 8 additives and manufacturers are very competitive. The additives are generally sulphur, phosphorous, or chloride based. This is a fertile area for research.

Don Buckley discussed a problem he has worked on with Exxon and General Motors 4 years ago in the lubrication of new diesel engines. The point is that industry called NASA (i.e., himself) to assist them in solving the problem that they were having with internal engine wear (rocker arms).

Not much in the way of basic research is going on in industry; they are concentrating on problem solving. Several large industries researched tribology and dropped it for economic reasons. Lewis, on the other hand, does tribology research by basic physical investigations. (Now referring to this as "Surface Science".)

Solid lubricants began 30 or 40 years ago with graphite. Currently all automobiles are lubricated by molybdenum disulfide. The Boeing 747 airplane, for example, has over 10,000 parts which are using solid lubrication.

Lewis is pioneering in very thin film lubricants, using metals deposited by ion sputtering and ion flooding. These fall into a general category of plasma physics techniques. Industry has taken a "show-me" attitude. However, one plating company in Dayton is now successfully using the ion-vacuum process developed by Lewis for thin film lubricant metal deposits. Don has a list of candidate "show-me" customers.

For another example, aluminum soft drink and beer cans need exceptionally good lubricant during their manufacture. They must roll the aluminum extremely thin, without it adhering to the rollers. Also, IBM is looking for very thin films (approximately 100 angstrom) to lubricate their tape decks. Timken roller bearings is the only company known to be doing some R&D on plasma physics techniques.

Lewis has several NRC sponsored foreign exchange visitors. From Japan, India, Israel, England. A total of 17 professors and 10 students.

Professional societies with which Don Buckley works are several. He mentioned American Society of Lubrication Engineers and ASME as examples. These two sponsor an annual technical meeting with industry which NASA participates in regularly as speakers, workshop and seminar leaders, etc.

A skilled group working on mechanical components-bearings, gears, seals-is being disestablished at Lewis. This group did important work in air bearings.

Don Buckley feels his laboratory (Surface Science) needs more visibility at NASA Headquarters.

### Preliminary Conclusions on Tribology (Surface Science)

1. The NASA technology looks good.
  2. Numerous industries are interested.
  3. The technology appears marketable, in that industry will pay money to interface with NASA on cooperative research projects.
  4. Needs to be followed, possibly by selecting specific products or techniques to be presented to industry.
  5. NASA appears to be in the forefront in this area of materials science.
3. Discussion with Dennis Flood.

Subject: Photovoltaic Energy Conversion

Purpose of this NASA research is to improve solar arrays for space application: a) for GEO; b) for space station in LEO.

For GEO, the driving concern is high performance rather than cost, because cost of material is diluted by transportation costs.

For space station in LEO, cost is the driver.

The terrestrial photovoltaic business is large. These companies will be in the space business. Lewis, however, is doing much less now with industry on terrestrial applications than it did in the past.

Lewis does basic R&D, up to prototype. They are now busy investigating the fundamentals of improving solar energy conversion.

Typical GEO array today produces 100 to 120 watts/square meter of array area.

The specific power is 30 to 35 watts/kilogram, using silicon.

Life of such arrays is approximately 7 years, defined as 75% power remaining.

For space station, the plan is to use silicon, as it is "flight qualified" by NASA.

Gallium arsenide is still coming up as silicon replacement, but it is very expensive. Japan appears ahead here.

Current cost of power from terrestrial photovoltaic energy converters is of the order of \$10 per watt. DOE goals are to reduce cost to 50 cents per watt.

Major companies in the business: Arco, Solarex, Mobile Tyco, Chevron. EPRI sponsors some solar research.

DOE funding of Lewis has disappeared by NASA decision. Therefore, they are phasing out all terrestrial applications. Phase out date is July 85.

DOE goal for terrestrial efficiency is about 10%. This uses amorphous silicon. Works in laboratory.

Equivalent space efficiency is about 8%. Not good enough for NASA.

Best solar super (silicon) cells, costs \$100/watt. Efficiencies are 14% space; 17% ground.

Manufacturers of space cells are Spectralab (Hughes) and Applied Solar Energy Corporation. The latter also makes ground cells. Hughes Research Labs also have ongoing research on space cells (working with Spectralab).

The U.S. market currently is for watches, calculators, etc., and it is quite large. Almost entirely supplied by the Japanese, who built small solar cells into these types of products. If U.S. prices for cells were to drop, this market could be captured.

The goal for gallium arsenide planar arrays is 20% efficiency in space and, 23%-24% terrestrial. Since gallium arsenide is such an expensive material, Lewis is working on a concentrator with a 100 fold concentration. The efficiency in space of this solar cell element should be about 22%; the system's efficiency 16% to 18%. They use a cassegrain mirror for concentrating sun rays. In laboratory at Lewis, they have demonstrated 19% cell efficiency to date; system would be 20% less (15%).

For space, GEO applications, gallium arsenide appears very desirable, because of the need for high efficiency despite the high material costs. Also, light weight is important for GEO arrays in order to minimize transportation cost.

In large solar arrays for LEO, more gains are still possible with advanced, high efficiency silicon cells in concentrated arrays. Even so, terrestrial use of such concentrator systems poses another problem, because of the need for sun tracking.

Thin silicon GEO cells are now of thickness of approximately 2 mils. The principal cause of damage to GEO arrays is particulate radiation (solar flare protons).

In LEO, radiation is not a big problem, thus cells can be made cheaper. Big costs of space cells is the paper work, also the low production.

The Japanese sell one megawatt/year worth of solar cells.

Lewis is also working on lower work-function materials. They are working on two or three layers of different materials with work functions as low as 1.7 eV.

In Dennis Flood's opinion, what needs to be done in terrestrial solar converters is first to up the efficiency, then worry about reducing the price.

Lewis is also looking at "Surface Plasmon" conversion of solar energy. This uses a thin metallic film which enters into "quantized" oscillation. The goal is to achieve 50% efficiency. This design is strictly on paper.

### Preliminary Conclusions on Photovoltaic Conversion

1. A significant element of technology appears to be the solar concentrator. The reason is that if built sufficiently cheaply, it could obviate the high initial cost of the cells. What is also needed is a configuration which need not be steered to track the sun.
  2. Solar converters do not appear at this time to be a high national priority. This is because of the change in the upward pressure on energy prices.
  3. Price is the big driver for terrestrial and LEO applications. Thus, reduction of price could capture the small appliance and other markets currently held by the Japanese, and perhaps create new markets for U.S. industry.
  4. An interesting future development might be the surface plasmon converter. NASA should investigate further how close it is to reality, costs, etc.
4. Discussion with Dr. Larry Thaller.

Subject: Electrochemical Energy Conversion and Storage

The Redox has been transferred to SOHIO, so there is little interest.

Lewis has been working for the last 4 years on nickel-hydrogen batteries (Ni-H<sub>2</sub>). This was also worked on by USAF for space uses. The advantage of Ni-H<sub>2</sub> as a secondary battery is a 10 to 15 year life, approximately 50,000 cycles life expectancy.

Specific energy 40 watt hours/kilogram to 80% discharge for Ni-H<sub>2</sub>. Lewis has made the initial cells; now has manufacturers making experimental cells and endurance testing the cells. They also looked into bipolar nickel-hydrogen batteries. They use a configuration different from the IPV (Individual Pressure Vessel). Thus, they achieve a higher volumetric density (20% lighter) than the IPV. Also, temperature is easier to control and they have longer life. Ford Aerospace has a contract to explore bipolar Ni-



H<sub>2</sub> battery technology.

The idea of the nickel-hydrogen battery development is to replace the nickel-cadmium batteries in use.

The regenerative fuel cell development has been taken over by the space station people. Making engineering model now.

Lewis has also looked into hydrogen-halogen (bromine, chlorine CL) batteries as an advanced, efficient concept. Problem is corrosive reactions.

The nickel-hydrogen type battery costs approximately 5 to 10 thousand dollars per cell capable of 40 to 50 ampere hours at 1.3 volts.

Probably the highest energy density for a rechargeable battery is offered by hydrogen/oxygen in regenerative fuel cells. This should provide (theoretically) 400 watt hours/kilogram.

Companies making these kinds of batteries are Yardney and Eagle-Picher.

In Larry Thaller's opinion there is no U.S. commercial market for nickel-hydrogen battery at this time due to the high costs.

They are investigating techniques at Lewis for making lighter weight, longer lasting nickel electrodes. The costs quoted of 5 to 10 thousand dollars per cell for nickel-hydrogen is 4 to 5 times that for equivalent nickel-cadmium cells.

Dr. Thaller indicates that the separator technology does not any longer constitute a problem. He does not believe that one can ever reach 1 kilowatt hour per kilogram. He also states that batteries are the slowest moving technology. The entire field has considerable lack of wisdom and intelligence. Hard to get money to support battery research.

In space applications the real problem is battery weight.

### Preliminary Conclusions on Electrochemical Energy Conversion and Storage

1. Dr. Larry Thaller's ultimate energy assumption differs significantly from that made in the New Look Study.
2. There appears to be no market for the current Lewis development.
3. The Redox development appears have been successfully transferred to industry.
4. There does not appear to be strong or significant interface with industry by Lewis in this area of technology.
5. Big application of batteries, according to Dr. Larry Thaller, is for primary cells for electronic applications.

APPENDIX E

NASA TECHNOLOGY CHARACTERIZATION

## APPENDIX E

### NASA TECHNOLOGY CHARACTERIZATION

From the RTOPs investigations conducted with responsible technical monitors at Langley and Lewis Research Centers (see Appendices C and D), the following technology opportunities were discovered. These are believed to be innovative "leading edge" technology opportunities that will be of interest to U.S. industry. They are listed here by applicable "generic" and "specific" areas of technology. Pertinent descriptions and general specifications in the form of raw data, are as understood from discussions with the cognizant NASA researchers.

A.        GENERIC TECHNOLOGY:  
            Materials/Composites

SPECIFIC TECHNOLOGY:  
Carbon Fiber Structures

1.    LaRC uses primarily graphite fibers in diverse configurations: chopped fiber blocks, continuous rods, filament-wound shapes, and laminated sheet "layups".
2.    The composites have great unidirectional strength. The strength is however not equal in all directions. This requires careful design; there is need to compromise strength, weight, and other properties to achieve design requirements. Current strength is equal to or superior to the best available for light-weight metals.
3.    In particular, the strength-to-weight ratio is higher than for Aluminum.
4.    The density of the composite material is 65% that of Aluminum
5.    Cost is up to \$50 per lb. for the raw material; \$100-\$150 per lb. for in-place material in aerospace structures.

6. The fiber technology can produce the complex shapes needed by the aerospace industry.
7. Composites are more difficult to machine than metals. Machining requires special drills, saws, etc.
8. Currently used resins exhibit only 15-20K psi tensile strength along the non-fiber-reinforced axis. There is a need for "tougher" resins.
9. The diameter of the individual fiber used is approximately 6 microns. Fibers are supplied by the manufacturers packaged in "tows" of 3,000, 6,000 or more fibers.
10. The currently small production implies high cost. The total U.S. production of carbon fibers is approximately three million pounds per year. (For Kevlar fibers, approximately ten times as much is produced).
11. Thermoplastics are being tried in substitution for resins, but they are sensitive to corrosion.

B. GENERIC TECHNOLOGY:  
Teleoperators

SPECIFIC TECHNOLOGY:  
Sensory Feedback

1. NASA is mainly interested in operator-driven systems.
2. NASA uses a complete "system" approach to research in automation technology.
3. As the degree of automation grows, man may give up some tactile and other stimuli in favor of increased "supervisory" mode of operation.
4. Directed control, i.e., partial closures of loop by certain sensors, can be attained in approximately 10 years.

5. Critical to #4 is the Transmission/Reception time delay due to the long distances involved in space. The threshold for a man to use "continuous control" is a maximum time delay of .15 to .25 seconds. Longer time delays require a "move and wait" mode of operation.
6. Current industrial manipulators have good positioning repeatability but poor initial positioning accuracy. Industry needs an active sensor to accurately define initial position accurately in three dimensions.
7. LaRC is establishing a data base of tests of accuracy and performance parameters of teleoperations.
8. Key techniques being worked on at LaRC labs include: simulation; conversion of tactile information into visual information; three-dimensional TV. Audio pattern recognition efforts previously conducted at LaRC, have been abandoned to universities for further research, as warranted.

C. GENERIC TECHNOLOGY:  
Power Conversion  
and Distribution

SPECIFIC TECHNOLOGY:  
Mega-ampere Switch

1. NASA (LaRC) is developing a high current (mega-amp) switch.
2. This is a gas, externally-triggered, automatically (reflectively) turned-off (perhaps turned "on" vice "off") switch.
3. Characteristics:

Pulse Repetition Frequency (PRF) = 1,000 cycles  
Pulse length = 10's of microseconds

Switching Power = 1 mega-amp up to 10's of mega-amps

Hold-off voltage = 100K volts down to 10K volts

4. The switch being developed fits into a 20 X 20 X 10 centimeter space.
5. The French are interested in this device for use in CERN.
6. Papers describing this switch development will be published during the next two years.

D.	<u>GENERIC TECHNOLOGY:</u> <u>Non-Destructive Evaluation</u>	<u>SPECIFIC TECHNOLOGY:</u> <u>High Resolution Ultrasound</u>
----	---	--

1. NASA's (LeRC) program is designed to develop tools to do more than detect flaws; e.g., determine certain physical microstructure characteristics of materials.
2. Ultrasonics is a prime tool which uses mechanical waves to measure mechanical defects in structural materials.
3. LeRC is using submerged testing techniques to allow water coupling between transducers and test material. Transducers can be scanned across test material in order to "image" flaws.
4. In ultrasonics most industries work with transducer frequencies from 1 to 25 megahertz. LeRC now uses up to 100 megahertz to probe micro-structure images of about 5 to 8 microns in lab-size samples.
5. The micro-structure scan measures variations controlling material "toughness". Material "toughness" is the ability to tolerate a crack without undergoing catastrophic failure.

6. Toughness correlations on relaxed materials are being done at LeRC (Langley may also be involved) by looking at microstructure variations.
7. "Toughness" is poorly understood. The toughness correlations being done at LeRC with microstructure measurements will help basic understanding.
8. Typical materials being investigated closely at LeRC are nickel-steels and tungsten carbides, in particular.
9. The LeRC system for high resolution ultrasound uses waveform digitizers (A/D Converter) to digitize high frequency signals. They ~~are now using a PDP 11/35~~ with 280K memory. This is considered to be a unique system.

E.

GENERIC TECHNOLOGY:  
Tribology

SPECIFIC TECHNOLOGY:  
Basic Surface Science  
Applications

1. The chief interests of LeRC experiments are: adhesion, friction, wear, & lubrication. Investigations are currently being conducted to determine the basic material properties that control these four parameters. Examples of these surface science applications are as follows:

Adhesion - glass to metal or ceramic seals in light bulbs

Friction - low wear materials for auto brakes & clutches

Wear - abrasive machine tools, such as grinders

Lubrication - oil for auto engines, as well as a vast array of oil additives

2. LeRC is pioneering in plasma physics techniques to deposit very thin metal films by ion sputtering. Timken is the only company known also to be working in this area at present.
3. LeRC is doing leading edge basic research. They could do much more cooperative work with industry in this field.



F.

GENERIC TECHNOLOGY:  
Photovoltaic Energy  
Conversion

SPECIFIC TECHNOLOGY:  
Solar Energy Concentrator

1. The main purpose of this NASA research at LeRC is to improve solar arrays for space applications.
2. Current prices (for terrestrial converters) are of the order of \$10 per watt. Department of Energy's announced goals are stated as 50 cents per watt.
3. LeRC is working on a solar energy "concentrator" with 100 fold concentration. The goal for solar cell efficiency, using gallium arsenide planar arrays, is 20% in space and 23% on earth. They are currently using a cassegrain mirror at LeRC.
4. Terrestrial concentrators pose the technical problem of "sun-tracking", in order to convert maximum solar energy each day.
5. Price is the most important consideration. There is a need for even more efficiency; however, as cost of gallium arsenide cells is very high.

APPENDIX F

EXAMPLE OF INDUSTRY PROFILE

"AEROSPACE" (SIC 366,372,376,381, and 382)

## APPENDIX F

### EXAMPLE OF INDUSTRY PROFILE

"AEROSPACE" (SIC 366,372,376,381, and 382)

This is an example which shows the possibility that NASA's emerging technological areas can be fitted or matched-up with the technological needs of profiled industries, thereby enhancing the chances for most effective technology transfer and utilization by industry.

## THE AEROSPACE INDUSTRY (SIC 366,372,376, 381 AND 382)

The Aerospace industry includes those subdivision that manufacture, research and develop complete military and civil aircraft and helicopters; engines for aircraft and helicopters; and missiles, space vehicles and their parts. Table 2-11 indicates these major products by Standard Industrial Classification.

This industry is second only to agriculture in contribution to balance of payments (\$15.4 billion in 1980) and represents the largest high technology product exporter in the U.S.

The Aerospace subdivisions accounted for 46% of the shipments of the Transportation Equipment subsector in 1980. By 1982, this was reduced to 33%. This decline was occasioned by a sharp reduction of civil aircraft and helicopter shipments associated with the worldwide recession of 1982-1983 and increased foreign competition in commercial transport manufacturing, e.g., Airbus Industries and several foreign general aviation aircraft manufacturers. Shipments accelerated in military aircraft and missiles during this same period but were not sufficient to offset civil aircraft and helicopters declines.

The business and structural profiles of the Aerospace subdivisions are summarized in Tables 2-12 and 2-13. The bulk of the indicators portray an internationally competitive, high technology industry with large R&D and capital investment requirements.

The production and sales of the aerospace industry can be conveniently divided into four categories:

- Civil Aircraft (including helicopters),

TABLE 2-11

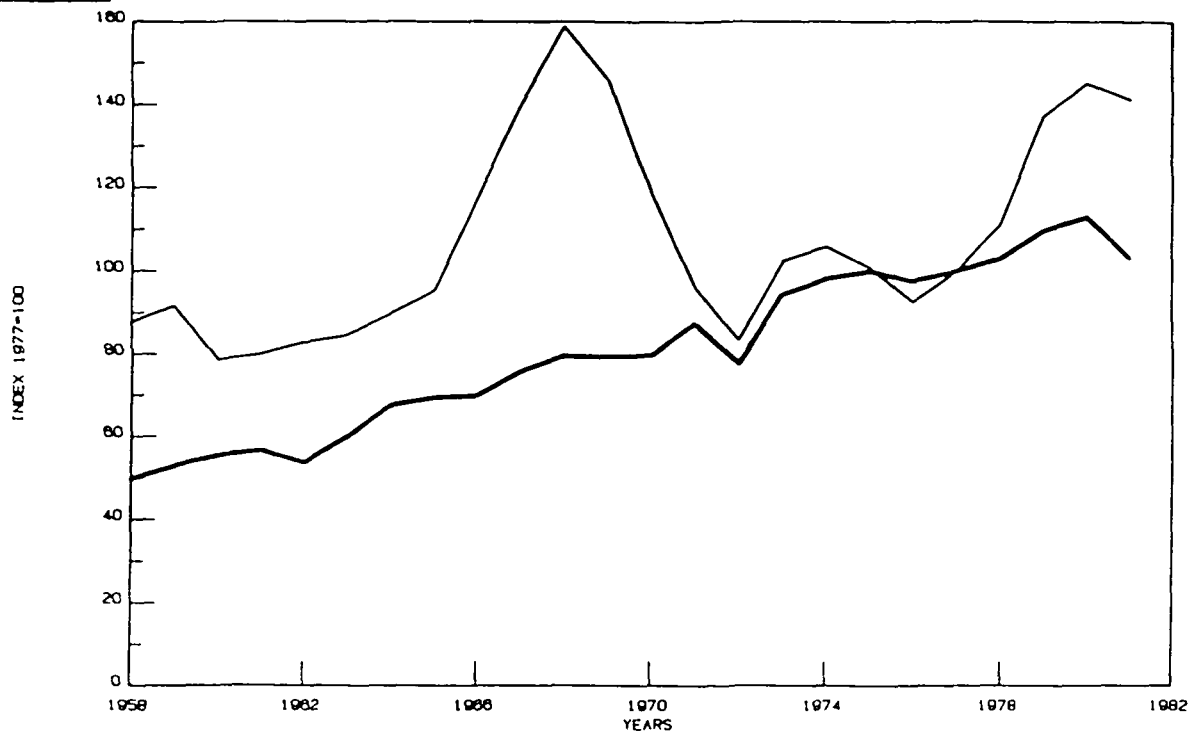
CLASSIFICATION OF MAJOR PRODUCTS OF THE INDUSTRY  
AEROSPACE INDUSTRY AND CONTRIBUTION TO AEROSPACE SHIPMENTS IN 1980

<u>SIC CODE</u>	<u>SUBDIVISION DESIGNATION AND TYPICAL PRODUCTS</u>	<u>% CONTRIBUTION</u>
372	<u>AIRCRAFT AND PARTS</u>  AIRCRAFT (INCL. HELICOPTERS) AIRCRAFT ENGINES & PARTS AUXILIARY EQUIPMENT ASSOCIATED RESEARCH AND DEVELOPMENT	79.0
376	<u>GUIDED MISSILES AND SPACE VEHICLES AND PARTS</u>  GUIDED MISSILES SPACE VEHICLES SPACE PROPULSION UNITS AUXILIARY EQUIPMENT ASSOCIATED RESEARCH AND DEVELOPMENT	21.0
SOURCES: U.S. DOC/ BOC: STATISTICAL ABSTRACT OF THE U.S., 1984; EOP/OMB STANDARD INDUSTRIAL CLASSIFICATION MANUAL, 1972		

TABLE 2-12

BUSINESS PROFILE OF THE  
AEROSPACE INDUSTRY

	<u>1977</u>	<u>1979</u>	<u>1981</u>	<u>1982</u>
<u>SALES (BILLION \$)</u>				
CURRENT \$	33.9	44.2	63.2	67.0
1972 \$	24.2	27.1	32.3	32.3
<u>INCOME TAX, % OF INCOME</u>	--	43.7	39.0	37.5



R&D EMPLOYMENT, 1982

95,000 (19% OF ALL INDUSTRY)

VALUE OF PLANT, 1982, CURRENT BILLION \$

\$12.7

NEW CAPITAL EXPENDITURES

CURRENT BILLION \$

1976 1982

1976

\$2.0

6.0

1982

BACKLOG

MONTHS

16

VALUE, BILLION \$

\$95.6

SOURCE: AEROSPACE INDUSTRIES ASSOCIATION

TABLE 2-13

STRUCTURAL PROFILE OF THE  
AEROSPACE INDUSTRY

<u>ESTABLISHMENTS (1977)</u> (CATEGORIZED BY NO. OF EMPLOYEES)		<u>LEADING FIRMS (1983)</u>	
		<u>NAME</u>	<u>SALES (BILLION \$)</u>
SMALL ( 20)	647	BOEING COMPANY	10.66
INTERMEDIATE (20-100)	542	McDONNELL DOUGLAS	8.11
LARGE ( 1000)	<u>91</u>	LOCKHEED	6.49
		UNITED TECHNOLOGIES	5.98
		MARTIN MARIETTA	3.90
TOTAL	1280	ROCKWELL INT'L	3.69
(1,133 COMPANIES)		GENERAL DYNAMICS	3.54
		NORTHROP	3.26
		TRW	2.60
		GRUMMAN	2.22
		RAYTHEON CO.	1.19
		FAIRCHILD	<u>0.89</u>
		TOTAL	52.53
NO. OF ESTABLISHMENTS ( 2500 EMPLOYEES)			
AIRCRAFT & HELICOPTERS		20	
AIRCRAFT EQUIPMENT		8	
SPACE PROPULSION		2	
AIRCRAFT ENGINES & PARTS		10	
GUIDED MISSILES & SPACE VEHICLES		12	
SPACE VEHICLE EQUIPMENT		<u>1</u>	
TOTAL		53	
		<u>OTHER</u>	
<u>PRODUCTION COST</u>	<u>MFG. LABOR</u>	<u>LABOR</u>	<u>MATERIALS</u> <u>ENERGY</u> <u>CAPITAL</u>
<u>DISTRIBUTION</u> , 1977	13%	18%	40% 1% 28%
<u>PREVALENT MODE OF PROCESSING:</u> BATCH, SMALL QUALITY, LABOR INTENSIVE			
<u>R&amp;D EXPENDITURES</u> , 1983 (\$ BILLION)			
INTERNAL			\$2.4
FEDERAL			\$9.4
SOURCES: AEROSPACE INDUSTRIES ASSOCIATION			
VALUE-LINE INVESTMENT SURVEY, 1984			
STANDARD AND POORS CORPORATION, 1984			

- Military Aircraft (including helicopters),
- Missiles,
- Non-Aerospace Products.

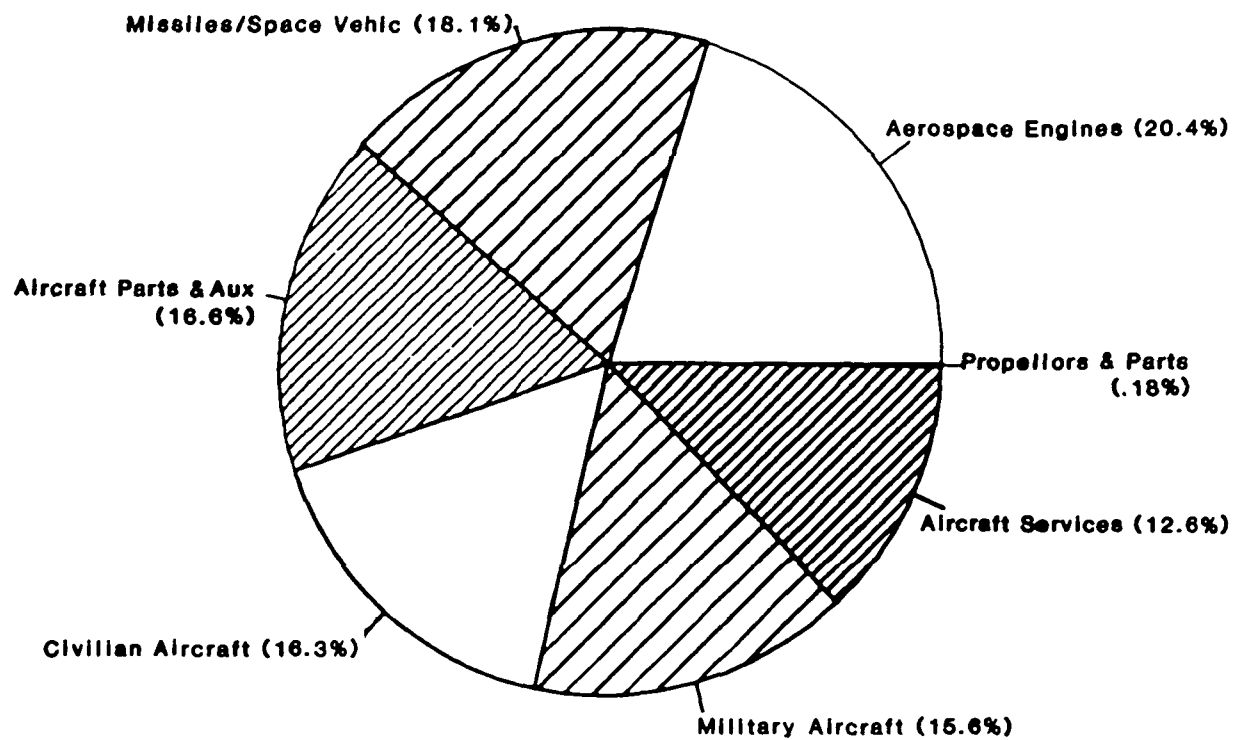
Product shipment distribution for 1983 is pictured in Figure 2-9.

The business profile (Table 2-12) shows total sales in 1982 current dollars of \$67.0 billion, essentially unchanged from the previous year in constant dollars. The 1982 dollar value of sales in all product groups in current dollar terms increased, but in civil aircraft production and non-aerospace sales declined. Profits measured as a percent of equity, assets, and sales continued to decline for the 1979 peak through 1982. Although total backlog for aerospace increased in 1982 by \$6.5 billion, this increase in real terms (\$434 million, constant 1972 \$) was small. An almost even split in backlog between U.S. government and other aircraft customers continued in 1982, with aircraft, engines and parts continuing their dominant (60%) traditional fraction of this backlog.

Table 2-13 portrays some of the key structural highlights of the U.S. aerospace industry. Slightly over half of all production establishments employ 20 people or less. The ten largest companies accounted for nearly 70% of product shipments in 1983. The production cost breakdown shows that materials costs amounted to 40% of production costs, labor costs amounted to 31%, while capital costs were 28%.

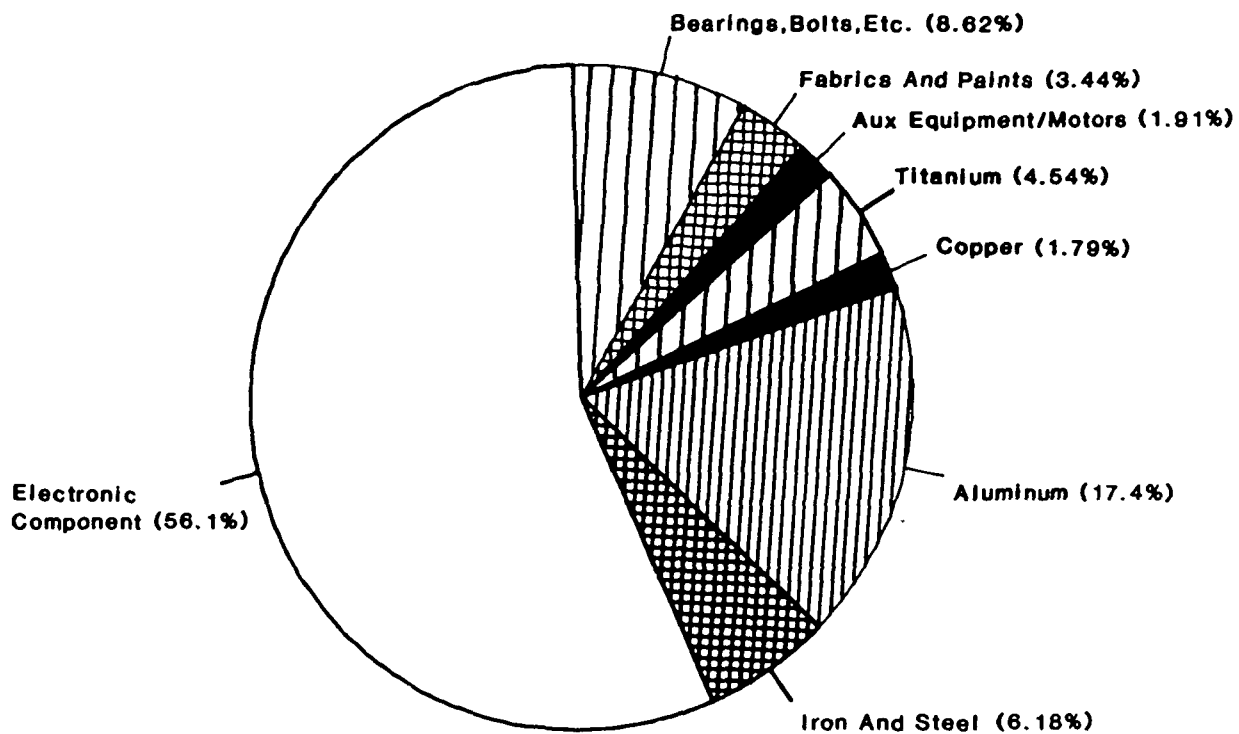
Figures 2-10 and 2-11 illustrate the proportion of production costs allocated for various materials and components of aircraft structures and engines. Electronic components are the most expensive aircraft materials, although these hardware prices should decrease as new technologies employing





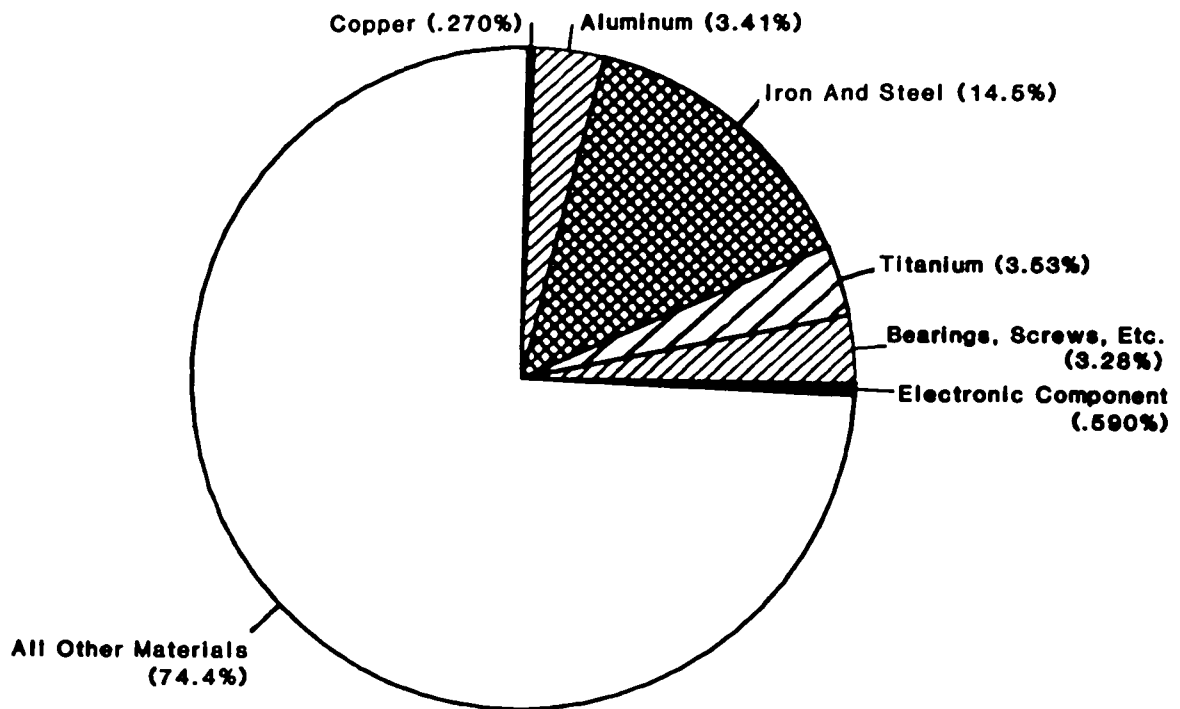
Source: U.S. Department Of Industrial Economics  
1984 U.S. Industrial Outlook

**Figure 2-9. Breakdown Of Aerospace Vehicles And Equipment Products Shipments (1983)**



Source: U.S. Department Of Commerce, Bureau Of Census,  
1977 Census Of Manufacturers

**Figure 2-10. Breakup Of Materials Used In Aircraft Airframe  
Manufacture - Based On Delivered Costs In 1977**



Source: U.S. Department Of Commerce,  
Bureau Of Census, 1977  
Census Of Manufacturers

**Figure 2-11. Breakup Of Materials Used In Aircraft Engine  
Manufacture (Based On Delivered Costs In 1977)**

microprocessor signal conditioning circuits (analog to digital, digital to analog) eliminate more costly instrumentation systems. Electronic equipment prices will continue to dominate materials costs as advances are made toward the all-electric airplane employing electromechanical actuators, digitized voice communications, flat-panel CRT (cathode ray tube) displays active control technology and digitized instruments and controls. The next highest portion of structural materials costs is spent on aluminum and its alloys. Aluminum constitutes 80% of the distributed airframe weight of a Boeing 767, one aircraft company, Martin Marietta, owns a mill that produces their aluminum requirements. Although aluminum prices have remained fairly stable in recent years, prices may increase gradually as a result of increasing energy prices and the increased use of aluminum in automobiles. Copper and steel are also important to the aircraft industry, especially in engines. Of all titanium mill products, 65% are used by the aircraft industry, especially in engines where its high strength at high temperatures is an essential characteristic.

Aircraft manufacturing labor is generally highly skilled. A large proportion (27%) of aircraft engineers work exclusively in R&D programs. Average aerospace industry employment for 1982 (1.16 million) declined slightly from 1981 (1.20 million), continuing at essentially the same level since 1978 and approximately 250,000 above the 1976 low for all aerospace employment. Average week hours (40.2 - 42.5 hours/week) and average weekly overtime (2.7-4.7 hours/week) have remained within relatively narrow ranges for 1972-1982. Both accession and separation rates for the industry from 1967-1981<sup>a</sup> show a continuing decline per employee per year indicating increasing employment stability (see Table 2-12). Scientists and engineers in research and development in the aerospace industry (95,000) represented approximately 19% of all research and development

<sup>a</sup> BLS data series terminated 1981

represented approximately 19% of all research and development scientists and engineers in all U.S. industry in 1982.

Capital costs make up 28% of production costs. Aircraft production plants are fairly new; the ten largest companies' average plant age is six years. Still, a large amount of capital is spent on newer, precise machinery. The trend in the aircraft manufacturing industry is toward coupled CAD CAM and flexible manufacturing systems, which allow engineers to make changes on a part's specifications on-line without having to shut down the assembly line to retool. Capital costs should continue to remain high as the aircraft manufacturing industry begins to rely increasingly on composites and other new materials technologies such as metal matrix based parts and powdered metal manufacturing.

#### Civil Aircraft Production

A three year decline in civil aircraft shipments continued in 1982 with delivery of 232 commercial transports as compared to 387 in 1981. Of particular note is the decline in orders (backlog) from foreign customers, reduced to 45% in 1982 from a previous high of 50%. Resurgence in this area is dependent on world-wide economic conditions and the fraction of this market captured by Airbus Industries or other later competitors which may enter the market. Civil helicopter shipments declined to 587 in 1982, a drop of 500 units from 1981. A similar reduction of general aviation aircraft shipments, from 9,457 in 1981 to 4,266 in 1982, occurred. Military aircraft sales increased again in 1982 in all categories; including 1,154 total aircraft sales and 685 foreign military and commercial sales.

#### Missile Programs

Missile production, including research and development increased by 20% in 1982 to in 1982. Total backlog declined from \$6.5 billion in 1981 to \$6.1 billion in 1982.

## Space Programs

Combined civil and military space system sales were up 16% to \$11 billion in 1982, with the FY1982 Department of Defense authorization for space programs (\$6.4 billion) exceeding NASA (\$5.5 billion) for the first time since 1960.

## Non-Aerospace

Non-Aerospace products and services reached \$11.5 billion in 1982, continuing a ten year increase. Little increase occurred, however, when measured in constant dollars.

The dominant factors which constrain the aerospace industry are shown in Table 2-14. The industry is highly dependent on federal military expenditures, 65% of the industry's sales are to the federal government in the form of military aircraft, missiles, and space vehicles; and the profit margin on federal sales is limited by government procurement regulations. The aerospace industry has large capital needs and is constrained both by the availability of capital (currently considered to be adequate) and cost of capital. It is estimated that \$3 billion years is required before a company can achieve full profitability after the introduction of a new medium-sized civil aircraft. The industry also requires a large number of trained engineering professionals who continue to remain in short supply. Market demands are highly cyclical, since they are based on economic strength and current DOD expenditures.

## Competitive Issues Affecting the Aerospace Industry

Aerospace companies recorded a strong export performance of \$15.6 billion in 1982 although this was down from the record 1981 performance of \$17.6 billion. The 1982 performance included \$9.6 billion in civil exports (down \$3.7 billion) and an all time record high of \$6 billion in military aircraft exports. Space

TABLE 2-14

CONSTRAINT PROFILE  
OF THE AEROSPACE INDUSTRY

GOVERNMENT INTERACTION	INDUSTRY HIGHLY DEPENDENT ON FEDERAL FUNDING FOR MANUFACTURING (\$16.8 BIL. DOD OUTLAYS VS. \$8.6 BIL. COMMERCIAL SALES 1982)
GOVERNMENT REGULATION	PROFIT MARGIN LIMITED BY GOVERNMENT PROCUREMENT REGULATION; MILITARY AIRCRAFT, MISSILES, AND SPACE VEHICLE SALES WERE \$43.7 BILLION IN 1982 WHICH WAS 65% OF TOTAL AEROSPACE SALES.
OWNERSHIP STRUCTURE	SMALL NUMBER OF LARGE, PUBLICLY HELD FIRMS (APPROX. 15) WITH MANY SMALLER FIRMS
QUALITY OF MANAGEMENT	INNOVATIVE MANAGERMENTS TEND TO LEAD OTHER INDUSTRIES
QUALITY OF ENGINEERING	HIGHER THAN AVERAGE FOR ALL INDUSTRIES (APPROX. ONE FOURTH OF PERSONNEL ENGAGED IN RESEARCH AND DEVELOPMENT)
AVAILABILITY OF ENGINEERING	SHORTAGE OF SKILLS EXISTS
AVAILABILITY OF INVESTMENT CAPITAL	CAPITAL GENERALLY AVAILABLE - MAGNITUDE OF NEW CIVIL PROGRAMS MAY EXCEED FINANCIAL CAPABILITY OF SINGLE COMPANY; \$2.0 BILLION REQUIRED OVER 4-YEAR PERIOD TO DELIVER MEDIUM-SIZE COMMERCIAL AIRCRAFT, AN ADDITIONAL \$1.0 BILLION REQUIRED FOR 2 YEARS FOLLOWING INITIAL DELIVERY FOR INITIAL HIGH PRODUCTION COSTS
MARKET DEMAND PATTERN	HIGHLY CYCLICAL
<p>SOURCES: AEROSPACE INDUSTRIES ASSOCIATION U.S. DOC/ITS: COMPETITIVE ASSESSMENT OF U.S. CIVIL AIRCRAFT INDUSTRY</p>	

vehicles and missile exports also increased by \$1.5 billion and \$1.4 billion, respectively. Thus, the U.S. aerospace industry recorded a positive trade balance of \$11.2 billion from 1968 to 1982.

The civil aircraft industry continues to be plagued by rising imports. In 1982, 92% of all aircraft imports (totalling \$1.2 billion) consisted of civil aircraft. Table 2-15 shows the countries that exported new civil aircraft to the U.S. and the amount of sales. A decline of \$2.0 billion in the 1982 aerospace trade balance is entirely a result of a decline in civil aircraft exports.

#### Productivity in the Aerospace Industry

The figure in Table 2-12, drawn from unpublished BLS data, indicates that the productivity (output per employee hour) rose steadily at a rate of approximately 3% per year through 1980, with the exception of a slight downturn in 1972. The use of CAD-CAM systems could increase productivity by a ratio of 2:1 up to 15:1. Figure 2-12 shows the production cost distribution of manufacturing labor. Introduction of a flexible manufacturing system would increase the proportion of labor costs spent on engineering, while reducing fabrication costs as well as some assembly costs. Figure 2-13 shows the cost distribution for the manufacture of commercial airplanes.

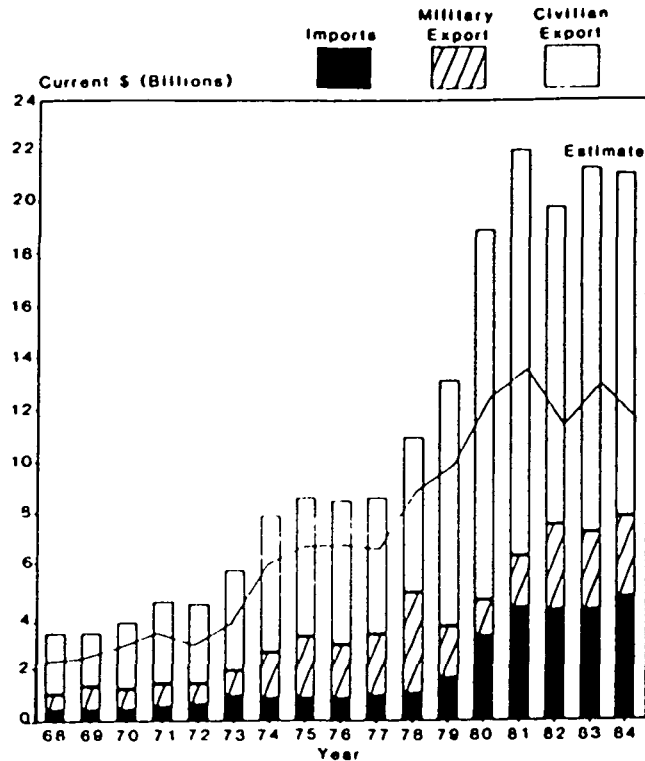
#### Role of Technology in the Long Term Strategic Outlook

The aerospace industry is currently characterized by impressive growth in new technologies for aircraft materials, design, and manufacture, as well as in how planes are flown. "Aeronautics technology is not yet mature in the sense of reaching diminishing returns for efforts expended . . . the prospective advances of the 1990s far exceed the evolutionary improvements of the 1970s and 1980s in improved



TABLE 2-15

COMPETITIVE POSTURE OF THE  
AEROSPACE INDUSTRY

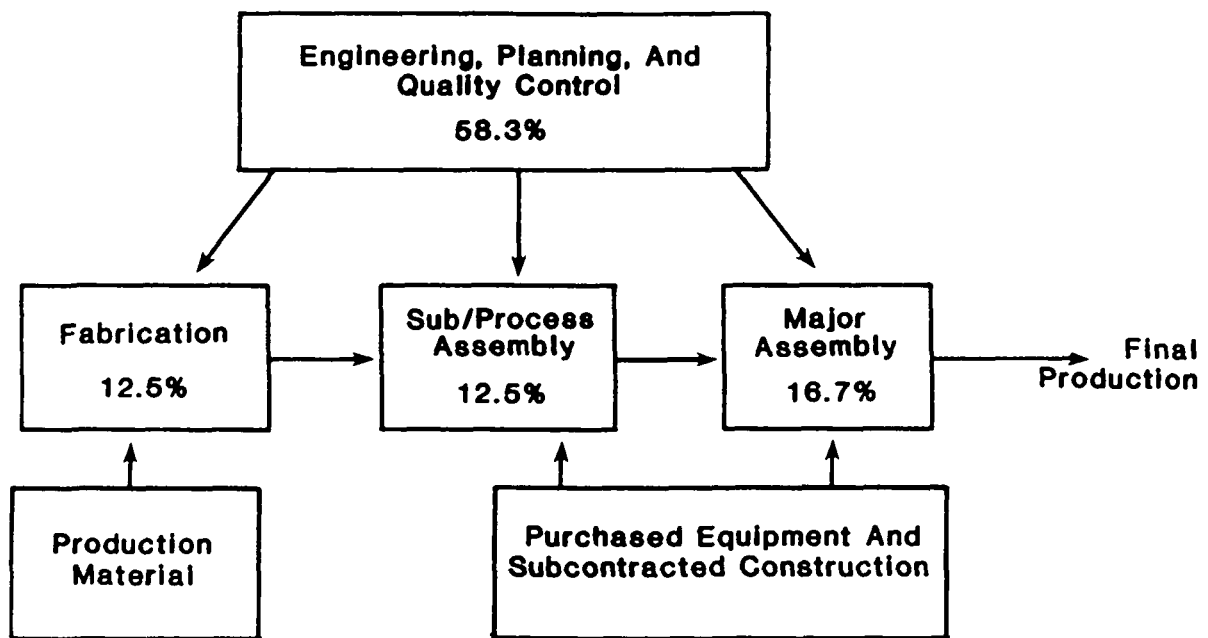
EXPORTS, IMPORTS & TRADE BALANCE

Sources Aerospace Industries Association  
U. S. Dept. Of Industrial Economics  
1984 Industrial Outlook

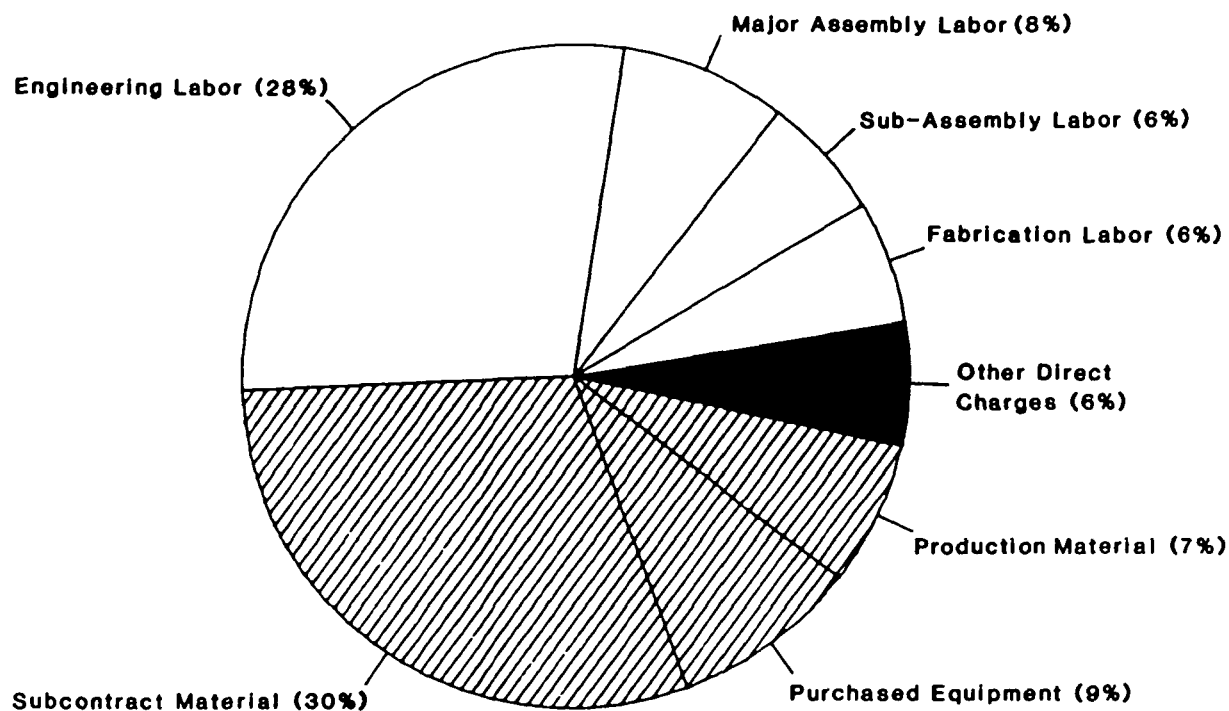
NEW CIVIL AIRCRAFT TRADE, BALANCE, 1982IMPORTS, 1982

<u>IMPORTS</u>		<u>EXPORTS</u>	
<u>COUNTRY</u>	<u>SALES TO U.S. \$ MILLION</u>	<u>CONTINENT</u>	<u>SALES \$ MILLION</u>
CANADA	307	ASIA	1,172
FRANCE	223	EUROPE	1,158
UNITED KINGDOM	144	MIDDLE EAST	730
ISRAEL	73	LATIN AMERICA & CARIBBEAN	517
BRAZIL	40	AFRICA	361
JAPAN	38	CANADA & GREENLAND	328
MISCELLANEOUS	100	OCEANIA	290
<b>TOTAL</b>	<b>1.0</b>		<b>4.6 BILLION</b>

SOURCE: AEROSPACE INDUSTRIES ASSOCIATION



**Figure 2-12. Commercial Airplane Production Process Average Manufacturing Labor Cost Distribution**



Source. Boeing Industry Data

**Figure 2-13 Commercial Airplane Cost Distribution - Average Airplane Based On First 200 Shipments**

capabilities."(Ref.1) Demand should rise for a new generation of quieter, more technically advanced aircraft to replace planes currently growing unprofitable or obsolete. For these reasons the U.S. aircraft manufacturing industry is defined as a sunrise industry.

Several advances in technology were mentioned earlier in this report's structural profile section. In order to clarify technological developments, advances in these technologies are separated into six categories:

- Aerodynamics,
- Structures and materials,
- Propulsion,
- Avionics,
- Flight controls, and
- Subsystems.

New aerospace technologies and their approximate era of diffusion are summarized in Table 2-16. Most of these technologies apply to all types of aircraft, but those that apply to a particular aircraft type will be noted as such.

#### Aerodynamics

Advances in aerodynamics include new computational methods and new flow control surfaces. "Computational aerodynamics could not enter a period of rapid development until the later 1960s when computers capable of solving the Navier-Stokes equations by finite difference techniques became available."(Ref. 2) Computational fluid dynamics are separated into four categories based on their levels of sophistication. They are:

TABLE 2-16

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## NEW AEROSPACE TECHNOLOGIES

TECHNOLOGY	DESCRIPTION	PRINCIPAL IMPACT	APPROXIMATE ERA OF SIGNIFICANT DIFFUSION 1985 1990 1995 2000
<b>AERODYNAMICS</b>			
<u>COMPUTATIONAL AERODYNAMICS</u>			
● STAGE 1	LINEARIZED INVISCID COMPUTATIONS FOR ATTACHED AIRFLOWS FOR SUBSONIC AIRCRAFT INCLUDING VORTICES AND BOUNDARY LAYER INFLUENCES	AIRCRAFT DESIGN, FLOW VISUALIZATION	
● STAGE 2	NONLINEAR INVISCID (EULER) COMPUTATIONS INCLUDING TRANSONIC AND HYPERSONIC FLOWS, AND BOUNDARY LAYER INFLUENCES	AIRCRAFT DESIGN, TURBULENT FLOW REDUCTION, FLOW VISUALIZATION	
● STAGE 3	REYNOLDS AVERAGED NAVIER-STOKES COMPUTATIONS THAT CAN INCLUDE SEPARATION, LARGE ANGLES OF ATTACK, UNSTEADY FLOWS, EXTERNAL AND ENGINE FLOW INTERACTIONS	AIRCRAFT DESIGN, TURBULENT FLOW REDUCTION, FLOW VISUALIZATION	
● STAGE 4	FULL NAVIER-STOKES CAPABILITIES TO COMPUTE TURBULENCE, CAN INCLUDE AERODYNAMIC NOISE, TRANSITION, SURFACE PRESSURE FLUCTUATIONS, AND TURBULENCE INTENSITIES	AIRCRAFT DESIGN, TURBULENT FLOW REDUCTION, FLOW VISUALIZATION	
<u>LAMINAR FLOW CONTROL TECHNOLOGY</u>			
● NATURAL LAMINAR FLOW	LAMINAR FLOW OVER WING AND FUSELAGE RESULTING FROM SMOOTHER SURFACE FINISH ON MODIFIED WING STRUCTURE	TRANSPORT AIRCRAFT 10% FUEL SAVINGS/ RANGE EXPANSION	
● MECHANICALLY INDUCED LAMINAR FLOW	SMALL HOLES ON LEADING EDGE OF WING ALLOW TURBULENT BOUNDARY LAYER TO BE REMOVED	TRANSPORT AIRCRAFT 10% FUEL SAVINGS/RANGE EXPANSION	
<u>STRUCTURES AND MATERIALS</u>			
● ALUMINUM TITANIUM ALLOY	LIGHT WEIGHT, HIGH STRENGTH ALUMINUM ALLOY	REDUCE STRUCTURAL WEIGHT	
● EPOXY	LIGHT WEIGHT, HIGH STRENGTH RESIN MATRIX MATERIAL	REDUCE STRUCTURAL WEIGHT	
● ADVANCED FIBER EPOXY	LIGHT WEIGHT, HIGH STRENGTH RESIN MATRIX MATERIAL	REDUCE STRUCTURAL WEIGHT	
● POWDERED METALS	ALLOWS PRODUCTION OF UNUSUAL ALLOYS AND SUPERALLOYS	REDUCE STRUCTURAL WEIGHT IMPROVE STRENGTH TO WEIGHT RATIO OF CERTAIN METALS	
● THERMO PLASTICS/ ADVANCED EPOXIES	HIGH TEMPERATURE, LIGHT WEIGHT, HIGH STRENGTH COMPOSITES	REDUCE STRUCTURAL WEIGHT, INCREASE STRENGTH	
● METAL MATRIX COMPOSITES	HIGH TEMPERATURE, LIGHTWEIGHT, HIGH STRENGTH METAL MATRIX COMPOSITES: CARBON OR CARBIDE FIBERS IN METAL MATRIX	REDUCE STRUCTURAL WEIGHT	
● CERAMICS	HIGH TEMPERATURE, HIGH STRENGTH ENGINE COMPONENTS	REDUCE WEIGHT, INCREASE THERMAL EFFICIENCY	
<u>PROPULSION</u>			
● ADVANCED HIGH BYPASS RATIO TURBOFAN OF 6-80C PW2037 (JT100)	ADVANCED TURBOFAN ENGINE ENCASED IN MORE AERODYNAMIC NACELLE FEATURING DIGITAL BLADE CLEARANCE CONTROL	REDUCE NOISE 5dB, REDUCE SPECIFIC FUEL CONSUMPTION 12% (1980 BASELINE), IMPROVE RELIABILITY AND DURABILITY	
● DIRECT DRIVE HIGH BYPASS RATIO TURBOFAN	ADVANCED TURBOFAN ENGINE (BPR=1.5) WITH DIRECT DRIVE COMPRESSOR	REDUCE NOISE, REDUCE SPECIFIC FUEL CONSUMPTION 15%	
● GEARED HIGH BYPASS RATIO TURBOFAN	ADVANCED TURBOFAN ENGINE (BPR=1.5) WITH GEAR DRIVEN COMPRESSOR FOR BETTER MATCH BETWEEN TAKEOFF AND CRUISE THRUST	REDUCE NOISE, REDUCE SPECIFIC FUEL CONSUMPTION 20%	
● HIGH SPEED TURBOPROP (MACH 0.71 TO 0.8)	ADVANCED HIGH SPEED, HIGHLY SWEEP, MULTI-BLADED TURBO PROP	REDUCE SPECIFIC FUEL CONSUMPTION 30%	
<u>AVIONICS AND CONTROLS</u>			
● FULLY DIGITAL FLIGHT MANAGEMENT SYSTEM (FMS)	FMS INTEGRATES INSTRUMENT OUTPUTS, COMMUNICATIONS, ENGINE, AND ENVIRONMENT CONTROLS AND PROVIDES PILOT WITH WARNING FOR DANGEROUS TRANSIENTS	REDUCE CREW WORKLOAD, IMPROVE CREW EFFICIENCY, ELIMINATES NEED FOR TWO CREW MEMBERS FOR COPILOT AND COMMUNICATIONS	
● FIBER OPTICS	REPLACE ELECTRICAL SYSTEM WIRE LINKS WITH FIBER OPTICS	REDUCE ELECTRICAL SYSTEM WEIGHT, INCREASE TRANSMISSION SPEED 1000 TIMES, ELIMINATE ELECTRICAL SYSTEM SUSCEPTIBILITY TO ELECTROMAGNETIC INTERFERENCE	
● MICROWAVE LANDING SYSTEM	F AA-DEVELOPED AIRPORT TRAFFIC AND AIRCRAFT NAVIGATION AID	REDUCE CREW WORKLOAD, REDUCE AIRPORT DELAYS AND AIR TRAFFIC LOADS	
● FLAT PANEL CATHODE RAY TUBE (CRT)	FLAT PANEL FLIGHT INFORMATION DISPLAY FOR IMPROVED RESOLUTION	REDUCE COCKPIT CLUTTER REDUCE CREW WORKLOAD	
● ALL ELECTRIC CONTROLS	ELECTRIC ACTUATORS	ELIMINATE HYDRAULICS, REDUCE WEIGHT, REDUCE COCKPIT CLUTTER BY ELIMINATING STEERING YOKES	
● INTEGRATED VLS/VHSIC	VERY LARGE INTEGRATION (VLSI) OF INSTRUMENTS AND CONTROL UTILIZING VERY HIGH SPEED INTEGRATED CIRCUITS (VHSIC)	IMPROVE WEIGHT TO POWER RATIO 10%, REDUCE CREW WORKLOAD TENFOLD IMPROVEMENT IN RELIABILITY OF SIGNAL PROCESSING	
● ADVANCED BRAKES/ STEERING	LIGHT WEIGHT CARBON BRAKES COMPOSITE STEERING STRUCTURE	REDUCE RUNWAY LENGTH REQUIREMENTS	
<u>MANUFACTURING SYSTEMS</u>			
● SPIN FORGING	TWO SPINNING ROLLERS SHAPE SPINNING WORK PIECE (FOR SOLIDS OF REVOLUTION)	REDUCE COMPONENT WEIGHT REDUCE ADDITIONAL MACHINING	
● FLEXIBLE MANUFACTURING	AUTOMATED WORK CELL CONSISTING OF COMPUTERIZED NUMERICALLY CONTROLLED MACHINING OPERATIONS WITH ROBOTICS TRANSFER MECHANISMS ADAPTABLE TO SMALL BATCH PROCESSES	INCREASE PRODUCTIVITY	
● INTEGRATED MANUFACTURING SYSTEM	FMS WITH DIRECT LINK TO CAD COMPUTERS	INCREASE PRODUCTIVITY, ENABLE DESIGNER TO UPGRADE PART DESIGN WHILE ON-LINE	

- o Stage 1 - linearized inviscid equations for attached airflows for subsonic aircraft including boundary layer and vortex influences (in use for the past ten years).
- o Stage 2 - inviscid nonlinear equations for subsonic, transonic, and hypersonic airflows including boundary layer effects (used for aircraft design since the late 1970s, although not yet mature).
- o Stage 3 - viscous Reynolds averaged Navier-Stokes equations to include separated flows, unsteady flows, large angles of attack, and external and engine flow interactions (limited use, although extensively researched; available in mature form during 1990s).
- o Stage 4 - full Navier-Stokes capabilities to compute rather than model turbulence including aerodynamic noise, transition, surface pressure and turbulence intensity fluctuations (currently being researched). (Ref. 2)

The benefits of industry use of computational fluid dynamics are reduced wind tunnel and flight tests costs, improved aerodynamics, a better understanding of fluid dynamics, and better designs based on turbulent flow reduction. The leading user of computational fluid dynamics is the turbine engine manufacturing industry.

Another exciting area of aerodynamics is the design and development of drag reducing external structures such as laminar flow airfoils and conformal weapons carriages (for fighters and military helicopters). Laminar flow control technology, when applied to long-range wide-body commercial aircraft, could result in a 20% to 40% reduction in fuel consumption. Turbulent drag is reduced on a laminar flow wing by sucking low-energy boundary layer air through small holes in the leading edge (first 10% of

chord length) of both upper and lower wing surfaces, which keeps the air flow attached to the wing and delays the onset of turbulent separation. Both Lockheed and McDonnell Douglas have tested this technology with NASA at the Ames-Dryden Flight Research Center. High aspect ratio wings (aspect ratio is the ratio of length to chord length) may also save fuel for long-range commercial aircraft.

Aerodynamic improvements on fighters serve a dual purpose: to reduce drag and improve maneuverability, and to lower the aircraft's radar cross section. Adaptive wing contouring for fighters could improve the supersonic lift-to-drag ratio 100%. Airfoils and fuselages modeled with computational fluid dynamics can be designed for vortex control, which would double the conventional fighter's maneuverability. Finally, shaping a fighter for a low radar profile also enhances the aircraft's aerodynamics.

## Structures and Materials

Weight reduction is a key goal in aircraft manufacturing. Over a commercial aircraft's 20 year operating life span, each pound shaved from a plane's weight could result in fuel savings of \$500 per year. Approximately half of a transport aircraft's weight is made up of structural components, while the other half is made up of subsystem weight. This section will be devoted to analyzing weight reduction and other benefits associated with applying advanced technology to structural components; the benefits associated with subsystem weight reduction will be considered in the controls section.

The current commercial aircraft's structural weight consists of about 80% aluminum, 15 to 20% steel and titanium, 3% composites, and about 1% miscellaneous materials. Use of composites such as carbon-fiber reinforced resin matrix materials, polyimides, fiberglass, and others should rise to at

least 30% of aluminum's proportion. Other materials that may replace aluminum are lighter weight, higher strength metal matrix materials (such as aluminum-lithium alloys), and aluminum-lithium-aramid laminates. Two projections concerning the increased use of composites or advanced aluminum alloys are portrayed in Figure 2-14.

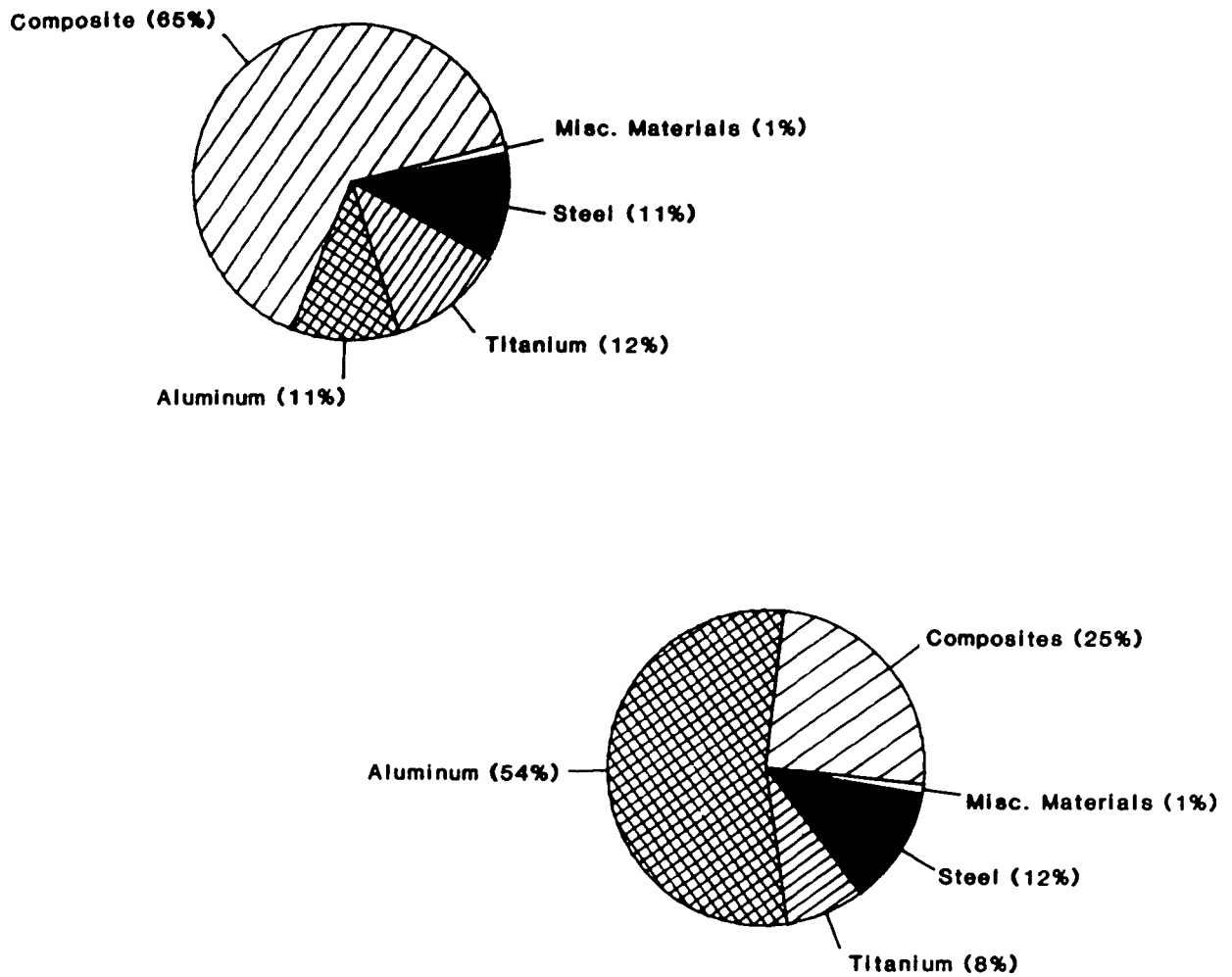
Composites are already being utilized, for some aft fuselage and elevator components. Further use of composites must be weighed against the use of aluminum alloys. One advantage of composites is that they can be formed into molds according to the required size and shape of components, which minimizes the amount of waste material created during production. Another advantage is that larger and simpler parts may be manufactured, thus reducing the need for fasteners while making assembly simpler. The fiber layout in composites may be specified to provide strength in the direction of stress distribution. Another advantage of composites is their low radar cross section in comparison with metals. A semi-porous carbon fiber composite would be an important component of laminar flow control wings, which would result in lower production costs (electron beam drilling would not be needed) and lower maintenance costs.

A significant disadvantage of composites as compared to advanced alloys derives from short term higher production costs, and from uncertainties concerning material strength and integrity. In order to utilize composites, production personnel must be retrained and production machinery retooled. In addition, some composites demonstrate reduced structural integrity caused by low velocity impacts from runway debris, rocks, and hailstone.

Aluminum alloys have been created with increased strength and reduced weight through powdered metal technology. Current alloys offer up to 50% weight reductions compared to aluminum. Although this weight reduction is not as great as is possible



### Materials Weight Distribution



Source: John E. Steiner  
Air Technology: The Transport Vehicle  
And Its Development Environment

**Figure 2-14. Potential Use Of Advanced Materials In Subsonic Airplane Production**

with composites, aluminum alloys demonstrate several comparative advantages. Metals typically have lower materials costs than composites. Use of advanced alloys allows conventional forms (sheet, plate, extrusions, forgings) to be used along with conventional design and manufacturing methods and current maintenance facilities and techniques. Expensive retooling and retraining would not be needed to produce aluminum alloys. Finally, analysis and use of metal alloys are simplified because of their isotropic properties.

Metal composites combine the benefits of metals and composites. Some of these materials are metal-matrix composites consisting of aluminum matrices reinforced with graphite, boron, alumina, or silicon carbide fibers. Metal fiber laminates also fall under this category. An example of a metal fiber laminate is Arall, which consists of 0.4 mm aluminum alloy sheets bonded with 0.2 mm layers of resin-based adhesive impregnated with unidirectional aramid fibers. Metal composites have most of the same advantages as aluminum alloys including resistance to corrosion and creep. Metal-composite laminates are especially resistant to creep since crack propagation is halted by the various laminate layers, although delamination could pose problems. Arall has a yield stress and ultimate tensile strength higher than aluminum alloys, while its weight is 30 to 40% less than aluminum alloys, and its impact strength is far superior to carbon fiber composites. Composite materials of comparable thickness and strength would cost two to three times as much as Arall, although Arall is more expensive to produce than monolithic aluminum alloys.

According to Laurens B. Vogelsang, professor of advanced materials at the Delft University of Technology, "If weight savings of 17% can be achieved, it is cost effective to replace aluminum alloys with Arall." (Ref. 3) Professor Vogelsang foresees the future aircraft as a combination of advanced materials: metals for engines and main wing components, Arall for fuselage

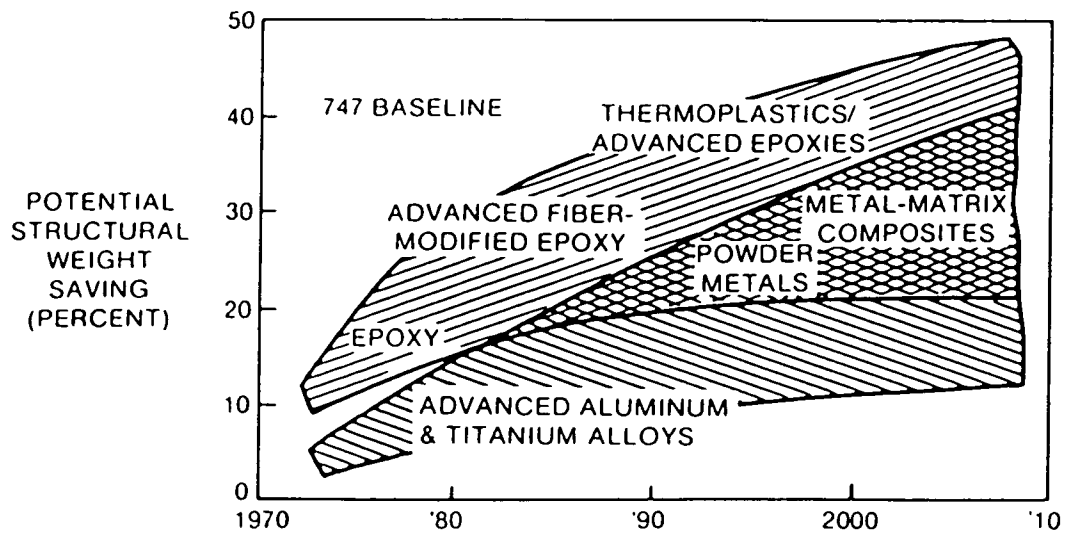
and underwing panels, and composites for wing leading and trailing edges. Figure 2-15 shows future structural materials that will continue the weight saving trend.

The contribution of titanium and steel to the structural weight of commercial airplanes will not likely decrease in the future. Potential cost savings for this portion of the plane's weight arise from cheaper manufacturing technologies. Explosive forming and bonding rely on the property of superplasticity exhibited at high temperatures by titanium and its alloys. Superplasticity is the ability of a material to be elongated extensively without localized thinning or rupture. Explosive forming and diffusion bonding at high temperatures could result in 10 to 15% weight reductions (without strength reduction), and with cost savings approaching 50% as a result of reduced machining and fastener use.

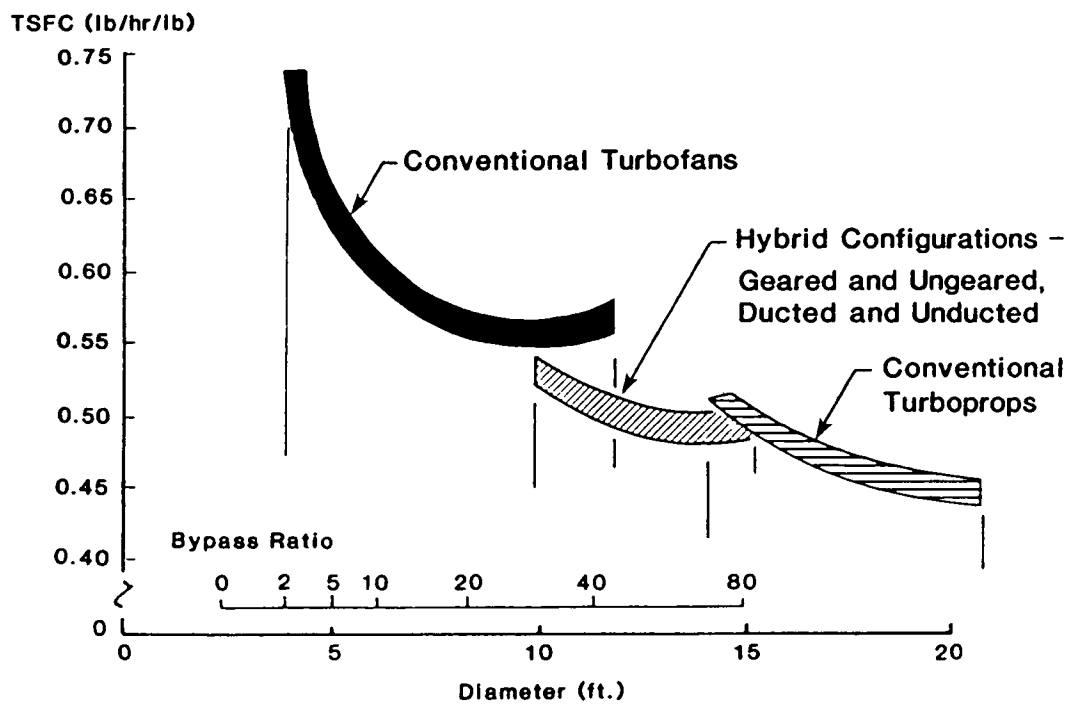
Another cost and machining reducing technology is spin-forging. Spin-forging reshapes a die-forged preform by driving two heavy, spinning rollers into the spinning preform at a precise, computer-controlled rate. Spin-forged parts require less machining to meet dimensional and surface finish requirements. The Aluminum Company of America (Alcoa) produced a turbofan engine nose cap that was 30% lighter than the pressed or die-forged counterpart. Spin-forging also enables the manufacture of parts with tapered thicknesses or special contours unavailable by conventional methods.

## Propulsion

The high bypass ratio (BPR) turbofan should continue to power large, intercontinental-range subsonic transport aircraft through the end of this century. Engine efficiencies are expected to increase 20% per decade during this time. Since the introduction of the low bypass ratio turbofan in the early 1960s, 40% improvements in total specific fuel consumption, as well as



**Figure 2-15. Future Structural Materials Trend for Potential Weight Savings**



**Figure 2-16. Specific Fuel Consumption Engine Size Trends**

the corresponding gains in engine efficiency, resulted from increases in bypass ratio (along with increases in diameter). Figure 2-16 shows that as bypass ratio increases, the total specific fuel consumption (TSFC) decreases. Future gains should be less dependent on increasing BPR, since higher BPR implies larger, heavier nacelles while contributing to a mismatch between takeoff and cruise thrust requirements.

The overall engine efficiency is the product of the thermal and the propulsive efficiencies. For future turbofans, the thermal efficiency will increase as a result of increased overall pressure ratios, higher component efficiencies, and higher combustor exit temperatures. The propulsive efficiency will also rise as low drag nacelles are developed, and as a result of some increases in BPR. In order to offset the incongruity between takeoff and cruise thrust caused by high BPR, new engine designs will move toward a geared cycle engine. This advance will enable the development of hybrid configurations, including unducted fans and turboprops.

The turbofan engine should also evolve better thrust to weight ratios as light weight materials are used to replace metals in engine components. Composites will be used for engine cases and support structures, as well as some internal applications, including rotor blades. High temperature polyimide-resin matrix materials have been applied to the core cowl and acoustic barrel of a conventional turbofan exhaust nozzle. Ceramics offer myriad potential benefits if applied to the turbine section, although their reliability and durability must be improved before utilizing them in such a high risk application. Potential benefits of ceramics are higher strength at higher temperatures (2500 °F, or a 30% increase over superalloy operating temperatures), one third lower density than superalloys, greater corrosion resistance, lower cost, and their availability from domestic resources (whereas the majority of strategic metals, such as chromium, cobalt, etc., that they would

replace are imported). Ceramic components are also easier to produce than machining extremely tough metals and have a better surface finish. Engines composed of composites and ceramics also have lower radar cross sections for stealth applications.

The turboprop offers even greater increases in propulsive efficiency since it can utilize low fan pressure ratios (across the propeller) without the massive nacelles that would be required for a turbofan to achieve the same low fan pressure ratio. In order to compete with other forms of commercial transportation aircraft, the turboprop engined aircraft must be able to achieve higher speeds (mach 0.8). Propellers for these applications would have multiple thin highly swept blades. Provided turboprop engine development continues at its present rate, these engines will be ready for testing by 1987, and ready for installation on medium range transports by the early 1990s. Turboprop engines offer potential fuel savings of 20% over turbofans. Adding counter-rotational propellers to the turboprop configuration to reduce swirl would result in about 7% additional fuel savings.

Small aircraft engines under investigation include diesel, rotary, and turboprop types. Potential supersonic propulsion improvements are not being pursued as aggressively.

#### Avionics

Advances in avionics will help to bring about the all electric airplane in which all data and controls are digitized. By integrating instrument outputs through very large scale integration (VLSI) with very high speed integrated circuits (VHSIC), the weight to power ratio for these components will decrease 70 to 80%, while reliability of signal processing will increase by a factor of ten. Data will be transmitted 1000 times faster via optic fiber, which also reduces weight and makes signals invulnerable to electro-magnetic interference (EMI) or,

for military applications, to an electromagnetic pulse (EMP). On-board computers will integrate these data for automatic trajectory and attitude control, thus reducing crew work load. Data from improved ground aids such as microwave landing systems and wind shear detectors will also be integrated with other flight data. At the core of this combined flight management system (FMS) is the inertial reference system defined by a laser gyro.

Data from the FMS will be displayed on several new space and weight saving devices. Flat panel cathode ray tubes (CRT) are already in use on military fighters as well as in the European Airbus Industry's A320. Holographic "head up" displays will make information readily available to the flight crew while performing a maneuver by displaying the information on the canopy in front of the pilot.

Other advantages of advanced avionics should not only relieve crew work load, but may well eliminate the need for a third crew member. Digitized voice communications will greatly simplify the communications officer's job. Navigation will also be simplified. Engine and environment controls will also be managed by the FMS for energy use optimization resulting in an increase in range by from 4 to 8%. The military could benefit even more from active and passive electronic sensors integrated with VLSI/VHSIC, which would result in improved lethality and survivability.

### Flight Controls

The most noticeable aspect of electric controls will be in the elimination of weight and complexity. Solid state electromagnetic actuators will eliminate pneumatic systems. Another advantage of replacing pneumatics with electric controls, in addition to reducing weight, is the elimination of bleed air requirements from turbofan compressors. Electric controls will

replace heavy control yokes with much lighter toggle switches or joysticks. All electric controls should reduce structural weight by 10%.

Active control technology is an integral part of the flight management system (FMS). A benefit of integrating active control technology with current aircraft technology is a stabilized plane during static or relaxed controls flying. Potential benefits of integrating active control with new structures, materials, and engines could result in even greater fuel savings as plane's control surfaces are reduced along with aerodynamic drag.

Another important factor in utilizing all electric controls is their price. Conventional analog devices are very expensive in comparison with the cost of simple transducers coupled with microprocessor integrated circuits required for a digitized flight information system.

### Subsystems

The switch to fully electric flight and environment controls is much better suited for the planes of the next few decades than hydraulic systems. Electric circuits and controls are much simpler and cheaper than hydraulics. Electric power is ideally suited for being extracted from the turbine shaft work, whereas compressor air bled for pneumatics detracts from turbofan performance. Electronics are also easier to maintain and replace.

Other subsystem advances that could improve aircraft performance are: 1) advanced brakes and steering systems will decrease runway length requirements; 2) advanced power distribution will directly benefit digital flight controls; and 3) closed loop environment controls will make military aircraft less susceptible to chemical warfare.



## Conclusion

Technology improvements are occurring in all sectors of the aircraft industry. "The many possibilities in the propulsion area are ample demonstration that the potentials in aeronautics will clearly outweigh the resources available for development." (Ref. 4) Industry officials are seeking government support for the focused development of various sectors of the aircraft industry. Benefits are optimized by integrating all of the advances in various fields into the future aircraft. These integrated benefits for large transport aircraft are summarized below:

- 30% increase in productivity
- 50% increase in payload and range
- 30% reduction in life cycle costs
- reduced operating costs - \$9 billion less for 100 plane fleet over 20 years.

For military fighters, the integrated benefits are as follows:

- 20:1 improvement in effectiveness due to increased lethality and survivability,
- 2:1 improvement in availability,
- 25% reduction in life cycle costs,
- \$14 billion less for 1000 plane fleet over 20 years.

New aerospace technologies and their approximate era of diffusion are summarized in Table 2-16.

In order to maintain a competitive posture against foreign, government-subsidized aircraft manufacturers, the U.S. aircraft industry, in conjunction with the federal government, must establish a set of goals for both the near term and the long range future aircraft development and marketing. Chief goals includes:

- To establish a timely and proven technology base, and
- To establish a government policy with respect to competing foreign industries that assures fairness in and access to both domestic and foreign markets.

The emphasis of this section has been on advanced technologies, while recommendations on government policy are beyond the scope of this report.

Development of an advanced aircraft technology data base is best suited for NASA. The DOD research is focused on near-term applications, while NASA should focus its research efforts on long lead, high-risk technology. Thus, NASA's budget should be expanded in order to research technologies that advance the state-of-the-art in the following fields:

- Advanced materials--especially to develop a manual of standards for existing composites, alloys, etc.
- Advanced engines--capable of burning currently available as well as future aviation fuels.
- Flexible computer aided manufacturing systems as well as coupled CAD/CAM systems--in-depth evaluation of available alternatives and manufacturing process risks and acceptability levels.

- Advanced aerodynamics--particularly computational fluid dynamics.
- Hypersonic flight--wind tunnel facilities and advanced experimental aircraft for actual flight testing.
- Advanced electronics and avionics--the all electric aircraft, navigational aids, and active controls.

Research in these fields is aided by achieving an understanding of the integration of the most advanced technology in an aircraft for optimum performance in the aircraft's designated task. NASA should also develop a viable mechanism for effective control of technology transfer as well as for exploiting foreign R&D.

## REFERENCES

1. Aerospace Technical Council of the Aerospace Industries Association of America, "Aerospace Technology for the 1990's", (Washington, D.C.: 1984) pg 7.
2. Benjamin M. Elson, "New Computers Will Aid Advanced Designs", Aviation Week and Space Technology, August 29, 1983, pg 55.
3. Michael Freazel, "Dutch Test New Structural Material", Aviation Week and Space Technology, November 28, 1983, pg 127.
4. John E. Steiner, "Air Technology: The Transport Vehicle and its Development Environment", National Academy of Engineering Nineteenth Annual Meeting, Nov. 3, 1983, pg 6.

APPENDIX G

RECORD OF INDUSTRY CONTACTS

## APPENDIX G

### RECORD OF INDUSTRY CONTACTS

**Note:** This Appendix contains listings of U.S. industrial technology requirements for selected industrial sectors and areas of technology. The listing of research activities was obtained from 20 different companies. These research activities are related to corresponding selected areas of NASA research and technology development. This list was derived from the non-attributable answers provided by 20 R&D managers when asked what their current R&D objectives encompassed. Only the research activities related to the NASA areas of technology being investigated are listed here. These provided a basis for further effort to match emerging NASA technology with industry needs.

<u>Area of Technology - Materials/Composites</u>	<u>Research Activities</u>	<u>Generic Industry</u>	<u>Standard Industrial Classification Codes (SIC)</u>
1. <u>Area of Technology - Materials/Composites</u>			
* High temperature metal and ceramic matrix composites for oxidizing atmosphere applications		Metals	3297, 3299
* Analysis of crack propagation as an energy absorption mechanism in metal matrix composites		Manufacturing (Mfg.) Metals	3297, 3299
* Properties and characteristics of metal matrix composites with trade-off analyses		Plastics, composites	3297, 3299
* Specialized applications of aluminum alloys at elevated temperatures (550 deg. F) in conjunction with powdered metals		Metals, Specialized Mfg.	3297, 3299, 3361, 3399
* Rubber modified-impact resistant resins		Special Mfg.	2821, 2822, 3069, 3079
* Panel fabrication using composite materials		Home/Storage Building	3079
* Methods by which carbon fibers can be stabilized		Chemical, Mfg.	3079, 3297
* Impact modification of epoxy resins		Mfg., Sports, Auto, Aircraft Parts	2821, 3069, 3079, 3728
* Fiber materials in the category of "non-metallics". Applications would involve communications, micro-miniaturization, integrated circuitry and lasers		TV, Computers	2824, 3079, 3229, 3662, 3811

APPENDIX G (Continued)

RECORD OF INDUSTRY CONTACTS

<u>1. Area of Technology - Materials/Composites (Cont'd)</u>	<u>Research Activities</u>	<u>Generic Industry</u>	<u>Standard Industrial Classification Codes (SIC)</u>
* Fiber, materials in the category of "metallics" with same applications as above		TV, Computers	3357, 3662, 3811
* Basic research in advanced materials such as polymers related to stabilizing for exposure to radiation to prevent long term aging		Building, Plastics	3079
* Organic coatings for applications in a "dirty" environment		Mining, Mfg.	2899, 3079
* Composite organic materials used at high temperatures		Mfg., I.C. Engines	2821, 2869, 3079
* High temperature resistant organic materials		Mfg.	2821, 2869
* Molding techniques for application to composite materials		Plastics, Mfg. Aircraft Parts	2869, 3079, 3728
* Explosive bonding research applied to composite materials		Mfg. Materials, Metals	3079

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<u>Area of Technology - Automation Technology/Robotics/Teleoperators</u>		<u>Generic Industry</u>	<u>Standard Industrial Classification Codes (SIC)</u>
<u>Research Activities</u>			
*	Controls systems when used with automated industrial equipment particularly with an operator in the loop	Mfg.	3622, 3823, 3824
*	Human factors relationships between man and machine when automated machinery operates in 6 degrees of freedom	Mfg.	3622, 3823
*	Computer vision and sensor-based robotic controls	Mfg.	3622, 3662, 3823, 3829
*	Robotic technology with emphasis on video and intelligence	Mfg. Robots, TV Games	3662, 3823, 3829, 3832
*	Sensor based robotic controls with learning capability for industrial applications	Mfg.	3622, 3662, 3823, 3829
*	Feed-back control devices or "adaptive controls" when used with artificial intelligence in automatic manufacturing systems	Mfg.	3622, 3823, 3829
*	Definition of the limits within which teleoperators operate	Mfg.	3622, 3829
*	Optical systems when used with teleoperators	Mfg.	3811, 3832
*	Human factors effects of automation on the total organization in a large, heavy equipment manufacturing plant	Mfg.	3622
*	Post-processor technology when used with automation technology such as robotics	Mfg.	3662, 3823, 3829, 3832



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#### 3. Area of Technology - Power Conversion and Distribution

<u>Research Activities</u>	<u>Generic Industry</u>	<u>Standard Industrial Classification Codes (SIC)</u>
* Electric motors and microprocessors including "servo-steppers"	Electric Equip. & Motors Mfg.	3621, 3679, 3699
* Power Factor Controller	Electric Equip. & Motors Mfg.	3613, 3622, 3679, 3699, 3825
* Methods by which information on energy could be collected and relayed to a central control center without hard wiring	Heavy Mfg.	3674, 3679
* Transmission of energy information over power lines	Heavy Mfg., Electric Utilities	3612, 3613, 3643, 3674, 3679
* Battery technology in general for energy conservation with emphasis on longer time between periods of charging. Application is for heavy duty manufacturing plants. Currently using lead/acid but would be interested in suitable substitutes.	Heavy Mfg.	2899, 3629, 3691, 3692, 3694
* Cost reduction methods in the conservation and/or re-use of wasted energy	Electrical, Heavy Mfg.	3622, 3674, 3679
* Temperature sensor technology as it is applied to energy conservation	Heavy Mfg.	3622, 3674, 3679
* Energy conservation for electric motors	Elect. Motor Mfg.	3621, 3679, 3699

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<u>4. Area of Technology - Non-Destructive Evaluation (NDE)</u>	<u>Research Activities</u>	<u>Generic Industry</u>	<u>Standard Industrial Classification Codes (SIC)</u>
* Failure prediction techniques when used with non-destructive evaluation		All Mfg.	20-39
* Failure mode analysis which results from non-destructive evaluation		All Mfg.	20-39
* Non-destructive testing during manufacturing processes		All Mfg.	20-39
* Analysis of crack propagation as an energy absorption mechanism in metal matrix composites		Metals, All Mfg.	3297, 3299
* Measuring techniques for determining surface configurations such as the sharpness of a cutting tool edge		Machine Tools	3541, 3545, 3549
* Materials for dies that have a low coefficient of friction and high wear resistance that operate at 600 deg. F. at point of contact		Machine Tools	3544
* Non-destructive testing and evaluation technology for general applications		All Mfg.	20-39
* Non-destructive evaluation as applied to gears		All Mfg.	20-39
* Non-destructive evaluation technology for application to definition of surface finish		Machinery, Slides/Rails	2911, 2992

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<u>Area of Technology - Tribology (Surface Science)</u>	<u>Research Activities</u>	<u>Generic Industry</u>	<u>Standard Industrial Classification Codes (SIC)</u>
5.			
*	General interest in tribology for a variety of applications in the field of aluminum speciality products	All Mfg.	2899, 2911, 2992
*	Non-toxic lubricants for medical applications	Special Medical Mfg.	2833
*	Materials for dies that have a low coefficient of friction and high wear resistance that operate at 600 deg. F. at point of contact	Machine Tools	3544
*	Very high film strength lubricants for metal drawing	Machine Tools, Mfg.	2992, 3549
*	Surface treatment of cylindrical shapes to improve wear and friction characteristics	All Mfg.	2899, 2911, 2992
*	Non-destructive evaluation technology for application to definition of surface finish	All Mfg. Slides/ Rails	2911, 2992

## APPENDIX G

### RECORD OF INDUSTRY CONTACTS

#### 6. Area of Technology - Photovoltaic/Electrochemical Energy Conversion/Storage

<u>Research Activities</u>	<u>Generic Industry</u>	<u>Standard Industrial Classification Codes (SIC)</u>
* Cost reduction methods in the conservation and/or re-use of wasted energy	Electrical, Heavy Mfg.	3622, 3674, 3679
* Temperature sensor technology as it is applied to energy conservation	Heavy Mfg.	3622, 3674, 3679
* Electric motors and microprocessors including "servo-steppers"	Elect. Equip., & Motors Mfg.	3621, 3679, 3699
* Power Factor Controller	Elect. Equip. & Motors Mfg.	3613, 3622, 3679, 3699, 3825
* Battery technology in general for energy conservation with emphasis on longer time between periods of charging. Application is for heavy duty manufacturing plants. Currently using lead/acid but would be interested in suitable substitutes.	Heavy Mfg.	2899, 3629, 3691, 3692, 3694
* Fluid REDOX (Redistribute Oxygen) system	Auto, Energy Storage	3694, 3714
* Advanced battery technology specifically in organic materials	Auto, Medical, Batteries Mfg.	3691, 3692
* Battery technology-nickel cadmium and lithium	Auto, Medical, Batteries Mfg.	3691, 3692

APPENDIX H

SPECIFICATION SHEETS

## APPENDIX H

### SPECIFICATION SHEETS

These Spec. Sheets contain the elaboration in Industrial terms of information received from NASA personnel who are directly involved with these emerging technologies. The Spec. Sheets were used as the basis for discussions with R&D personnel (and/or executives) of targeted companies or technical organizations, in order to better ascertain their level of interest in the respective technology area.

SPEC. SHEET  
FOR  
MATERIALS/COMPOSITES

CARBON FIBER STRUCTURES  
(HERCULES AS 4 FIBER - 3501-5A PROG. RESIN)

**Composition by Elements:** 60% Carbon Fibers + 40% Resin - by weight  
Normal reference = "50-50" by volume.

**Shape, Form, and Condition of the Structure:** Can form any shape, especially when hard rigid shapes.

**Diameter of the Fiber:** 7 to 8 Microns (1/3 the diameter of human hair)

**Fiber Contents of the Composite Material:** Same as above.

**Strength of the Structure:**

Tensile: 400,000 to 500,000 psi

Flexure: 260,000 psi

Yield: Not much, but elongation = 1.3%

Laminar Shear = 19,000 psi

Hardness: Same as resin

Density: 1.7 to 1.8 grams per cubic cm.

Modulus of Elasticity: 34 to 35 Million psi

Flexural Modulus:  $18.7 \times 10^6$  psi

Tensile Modulus:  $20.7 \times 10^6$  psi

**Special Properties:**

Thermal Expansion Coefficient:	Longitudinal	-	0.1	to	$0.2 \times 10^{-6}$
					inches/inch/ <sup>o</sup> F
	Cross fiber	-	$10-20 \times 10^{-6}$		
					inches/inch/ <sup>o</sup> F

CARBON FIBER STRUCTURES page 2

**Thermal Oxidate Resistance:**

Short term - retain full strength up to 1,000°C  
At 316°C - lose 0.18% of its weight during 700 hours

**Thermal Conductivity:** 0.032 Cal/cm/sec-°C

**Electrical Resistivity:** 1,500-5,000 ohms/cm/foot for 10,000 filament tow

**Volatile Contents If Any:** None

**Costs:** For continuous fibers = \$15 to \$20 per pound

**Applications:** NASA only

General: Secondary structures, i.e., Boeing 757, 767 floors & spoilers, ailerons, rudders, and "filleting" (wing to body).

Special: Spacecraft; i.e., platform for space telescope for thermal stability

**Special Remarks:** Expensive! Trying to get costs down--then more people will find uses.



SPEC. SHEET  
FOR  
TELEOPERATORS

**Type of Sensor:** Currently working with the following for teleoperator arms

- Position Sensors
- Force Feed Sensors
- Strain Gage Sensors
- Touch Sensors

**Objective:** To identify unmarked target for its state

**Performance Characteristics:**

- Repeatability to .003"
- Velocity range
  - = 6 degrees of freedom in x,y,z plane
  - = undefined flexibility
  - = arm movement of 2 ft./sec.

**Load Carrying Capacity:** Not specified, but if inertia increases, the arm's speed is decreased

**Teleoperator System Requirements:** System currently consists of two arms that are each 50 feet long

- Power - not specified
- Accuracy - not specified
- Resolution - not specified
- Weight - not specified
- Time delay - maximum of .15 to .25 seconds for continuous control

SPEC SHEET FOR TELEOPERATORS (Continued)

**Application:**

Specific - Space Shuttle Maneuvering Arms

General - Terrestrial operations in hostile environments (military, nuclear, fire, underwater, mines, etc.)

**Remarks:**

Presently in research and development phase, and it may take several years before teleoperator system specified can be finalized for commercial application.

SPEC. SHEET  
FOR  
PHOTOVOLTAIC ENERGY CONVERSION

SOLAR ENERGY CONCENTRATOR

**Type and Shape:** Two mirrors 1) Hyperboloidal Surface 2) Parabaloid of revolution  
(3 dimensional cut of a sphere)

**Fixed/Movable:** Fixed/can be made movable if arranged on a large plate

**Degree of Concentration:** 100 times (Expected 125 X)

**Efficiency of Concentrator:** 16% Air mass to zero (satellites); note air mass  
to 1 = noon direct sun; air mass to 2 (worst  
condition sunset)

**Concentrator Material:** Silver-plated Electroformed Nickel, also looking  
at other materials

**Reflective Index of Material:** Silver over 80% (Solar Cell Eff. 20%)

**Terrestrial Environment Effects:**

- Temperature - no problem for gallium arsenide 80-85° C
- Humidity - no problem, any stable coating will do
- Pressure - no problem
- Electrical Arcing - 1.2 volts for each cell

Note: All LeRC work is for space environment

**Concentrator Material Quality:**

- Dust - single coatings degrade output, thinking about  
hermetically sealing cells.
- Fungus growth - not worry-organic adhesive silicon rubber
- Corrosion -- no problem

SOLAR ENERGY CONCENTRATOR (Continued)

**Solar Cells Material:** Gallium Arsenide

**Tracking:** Perpendicular 2% accuracy

**Cost:** No Comments

**Application:** All space (no terrestrial work)

**Remarks:**

- LeRC uses a "converter element" which consists of 2 concentrators (a primary and a secondary mirror) focused on a solar cell. The element is rigid and measures about 2" in diameter x 1/2" thick. The concentrator can be characterized as a "cassegranium mirror".
- All LeRC work is aimed at space applications. NASA is no longer working on terrestrial applications.
- Other contacts are:
  1. EPRI in Palo Alto
  2. Varian in California
  3. Sandia Labs, N.M. (Jim Wiczer). They are looking at 1000 X concentrators
- Some people are talking about using concentrators to generate heat through steam. Don't know who they are, but it was discussed at a DOE meeting.

SPEC. SHEET  
FOR  
POWER CONVERSION/DISTRIBUTION

MEGA-AMPERE SWITCH

**Type (Gas/Air):** Gas  
(Insulating and Lubricating Media)

**IF GAS - type of gas (SF 6):** Hydrogen

**Pulse Repetition Frequency:** Too early to tell from his R&D. But expect to get 1,000 to 10,000 cycles per second. But this is a goal only.

**Pulse Length:** Variable, but in the 1 to 100 microseconds range.

**Switching Power:** Their applications are not used in this mode. See remarks.

**Hold-off Voltage Range:** 10,000 to 20,000 volts

**Continuous Current:** Complicated subject-preferred to skip it.

**Interrupting Current:** Not used as a circuit breaker. Theirs is a closing (Short Circuit Current) switch, not an opening switch.

**Size:** 6" X 6" X 6"

**Weight:** Couple of pounds.

**Application:**

- Special-Current switch for pulse to electrically driven lasers.
- General-No Comment.

**Costs:** Work is R&D, therefore costs would be misleading.

**Remarks:**

LaRC is using switches in Pulse Mode only. Power is shut off automatically after short term pulse or turn-on. Not used as a "circuit breaker".

SPEC. SHEET  
FOR  
NON-DESTRUCTIVE EVALUATION  
HIGH RESOLUTION ULTRASOUND

**Type (Submerged/Non-Submerged):** Use Both - Submerged-when piece can fit into tank because water is a better transmitter. All Others - Non-Submerged.

**Focused/Unfocused:** Both - Focused for better resolution. Unfocused for large areas fewer passes, faster scan.

**Frequency:** 1 To 100 Megahertz

**Band Size:** Broad-Depends on Frequency (5 to 50 Megahertz)

**Electric Pulse:** Short Duration - Spiked (Spiked/Rectangular/Other)

**TRANSDUCER/RECEIVER**

**Characteristics:** Barium Titanate

**Signal Processing:** Both Amplitude and Spectrum - Amplitude or "Time Domain" (Response to question simply helped define headings-Applications varied). Look at the Frequency Spectrum.

**Structure Size Probed:** 1/4" To 1" Diameter

**Costs:** Approximately \$ 75K for Tank & Peripheral Equipment & Computer to scan (not to store data).

**Applications:**

1. Metals/Alloys
2. Composites (Metals/Non-Metals)
3. Ceramics

**Remarks:** Major thrust in NASA is to determine material characteristics (Microstructure, etc.) Exclusive of flaws. Flaw detection important but plays small role in their work. Basic work in the R&D beyond state-of-the-art. Regarding industry comment "20 Micron Flaw detection"--if they can get that they are doing good work. Does not agree with industry comment that this method "can only detect flaws--not characteristics". His work can!

APPENDIX I

RECORD OF CONTACTS WITH INDUSTRY PERSONNEL  
IDENTIFIED AS PROSPECTS FOR SELECTED  
NASA TECHNOLOGIES

## APPENDIX I

### RECORD OF CONTACTS WITH INDUSTRY PERSONNEL IDENTIFIED AS PROSPECTS FOR SELECTED NASA TECHNOLOGIES

Note: These summarized conversations with industry contacts resulted from the use of spec. sheets to discuss NASA technologies with industry. The spec. sheets facilitated communication and evoked the responses herein. The selected industry contacts all verified the validity of the matching process by their positive interest.

1. a. Baltimore Gas & Electric Co. - Solar Concentrators

We originally earmarked B.G.&E. for photovoltaics, and narrowed our investigation down to Solar Concentrators. After talking to 3 different people, we finally reached Mr. Charles Powell who is their Director of Research. His comments were basically that most electric power companies--at least on the East Coast--are limited in their prospects for solar collectors because the amount of solar energy available to them appears to be low. In fact, they are now in the middle of a study to determine exactly how much solar energy is available throughout the year. Most of their R&D work is centered on solar-thermal activities. He did not feel that work on solar concentrators was "attractive". He suggested that the Electric Power Research Institute (EPRI) might be interested in our work and gave us a name to call: Ed DeMeo in Palo Alto. He also said that some other utilities in other parts of the country were showing an interest in solar collectors and noted that they were located in the Southwest, Northwest, and also the Public Gas & Electric Co. of New Jersey. These can also be contacted, if more data points are needed.

b. EPRI - Solar Concentrators

The EPRI contact was later changed to John Cummings who is the head of Renewable Resources (415-855-2000 X 2166). Caller followed up on the B.G.&E. suggestion to call EPRI and talked to John Cummings. He is the Department Head of Renewable Resources and therefore has the job of working on solar concentrators. He is



very knowledgeable in this field. According to John, he believes EPRI is ahead of everybody on concentrator R&D. In answer to questions about NASA's R&D vis-a-vis EPRI's work, he said NASA has a different mission, which is space oriented, and therefore he could not make any judgements regarding the quality of NASA's work. He is very familiar with all of NASA's field center work. Caller read him our spec sheet, but he didn't seem impressed because the applications are different. For instance, he said that the key to providing bulk electric power on the ground requires a photoelectric or photovoltaic cell approaching or exceeding 25% efficiency, which is very difficult to do, even if the solar concentrator is around the 500 X level. Therefore, EPRI is focusing their work on improving the cell efficiency rather than the concentrator efficiency. However, he wants to be kept informed of NASA's work in case they make improvements in either area.

2. a. Union Carbide - Carbon Fiber Structures

This contact took at least 7 conversations to get the right person. He was Mike Lella (203-794-2000) at Hackensack, N.J. Caller talked to corporate headquarters in Danbury, Conn., but each person said he had only a cursory knowledge of the subject and asked caller to talk to someone else. All this points to the difficulty in dealing with the large Fortune 500 companies, which was the opposite of talking to small companies, as will be seen in the Teleoperator field which follows.

The investigator read the spec. sheet to Mike Lella, but he did not want to discuss any one point in detail. He preferred to talk in general terms. His overall comment was that his company was indeed interested in NASA's work in carbon fiber composites, but to what degree depended on which part of NASA's work would be of interest to them. When it was again attempted to review our spec sheet, he said there were too many people involved in their R&D for any one person to make a specific comments. He then proposed that ECOsystems send him our spec. sheet, and he would circulate it throughout the organization to find out everyone's specific interests. His address is:

Michael Lella  
Union Carbide Corp.  
1 Union Plaza  
Hackensack, New Jersey 07602

b. Boeing Company - Carbon Fiber Structures

The Washington, D.C. Office of the Boeing Company was visited to discuss carbon fiber composite structures after discussions at Langley Research Center. Mr. John Stratham discussed carbon fiber composites from his company's perspective as the world's leading commercial jet airplane manufacturer. He stated that all secondaries; e.g., ailerons, rudder surfaces, etc. are currently made of graphite (carbon fiber) composites. The use of the composite secondaries saves approximately 1,500 pounds on the empty weight of the Boeing 757 and 767 airplanes.

The major problem for Boeing in the use of carbon fiber composite structures is cost. They are costly because the manufacture of the composite structure is too labor intensive. The raw material costs approximately \$50 per pound, and it must be in final place on aircraft for no more than \$100 to \$120 per pound. The need is to invent new automatic tooling, and/or to reduce the raw material costs, before composites can be more widely used by Boeing in aircraft structures. A contributing factor holding costs high is the fact that the quantity of composite material being produced is still small.

As regards the increased use of carbon fiber composite structures, Mr. Stratham advised also that a big problem exists with the resins. This is in addition to the real problems encountered during manufacturing with composites. The advent of some good thermoplastic will greatly alleviate manufacturing problems and reduce costs, since it would allow the molding of large, intricate structures.

In the informative material that Boeing provided, the meaning is not that the technology is what is evolving now, but to a large extent the meaning is what ought to be done. He believes that Boeing is ahead of LaRC in the testing of large single structural pieces of composite material; however, he thinks LaRC is leading in the chemistry of resins. On the whole, NASA was seen as doing a very good job in supporting the aerospace industry in this and other areas of technology, such as NDE. Boeing desires to continue working closely with NASA in the development of carbon fiber composite structures and in high resolution ultrasonics (NDE) for use with these structures.

3. a. Unimation, Inc. - Teleoperators

Tried over 2 days to reach the right person. The head man is in Europe and his Deputy, Mr. Vin Jalbert (203-796-1800 X 1138) was difficult to reach. So caller decided to try another smaller company.

b. Teleoperator Systems, Inc. - Teleoperators

After only 2 tries, caller reached Carl Flatau who is the President and COB. He knew all there was to know about what his company in Bohemia, N.Y., is doing and what everybody else was doing, including NASA. This is in direct contrast to how one reaches the right person vis-a-vis large Fortune 500 companies. He corrected caller by saying he preferred to call his work, "telepresence" as Dr. Castruccio will be very happy to hear! He receives TU's Tech Briefs Journals, and he reviews them regularly. He is therefore aware of what is going on through the publications mode. He said he knows the people at NASA and would be happy to become involved in any activity in this field. However, he would like to talk on specific areas rather than on broad terms. Therefore, ECO could send him a spec sheet, so that he could look at it in great detail at his own pace.

He has worked for a long time in this field as a member of the "Robots International" and the "American Nuclear Society". In the latter organization, he is the chairman of the committee for New Applications. He worked on the orbital manipulator as a key consultant (for the Shuttle), and he worked on assembly in space projects with Grumman Corp. He also said they are working on "remote operation of robots" - which is a very interesting innovation.

c. Baltimore Gas & Electric Co. - Teleoperators

Mr. Wilkens was contacted first at BG&E to discuss user requirements for teleoperator sensory feedback at their nuclear power plant. He referred us to Mr. Bob Denton (301-260-4724) who is Supervisor, Training and Technical Services, for BG&E's Calvert Cliffs nuclear power plant. As a result of these contacts, it was determined that BG&E is indeed interested in teleoperator technology for application at Calvert Cliffs. After hearing the spec. sheet, he requested documentation of NASA's technology. Their major application for teleoperators is to prevent direct exposure of humans to nuclear radiation. They would be interested in "joining hands" with NASA for applicable

technology transfer. BG&E has spent money for research in the nuclear safety area, and expects to spend more. They would like to explore the feasibility of teleoperator technology with NASA for applications at their nuclear power plant.

d. Bureau of Mines - Teleoperators

At Washington, D.C. Headquarters of the Bureau of Mines, Dr. David Forshey of the Health and Safety Office was contacted. He was interested in teleoperators from a mine safety policy viewpoint, and he referred us to Mr. Thomas Fisher, Robotic Research Group, Pittsburgh, PA. (412-675-6648). Mr. Fisher has been doing considerable work in robot applications for mining. He has been working extensively with NASA on this already. The purpose of BuMines research program is both for safety and increased productivity. BuMines has been testing newly developed devices and inviting mining companies to conduct actual usage tests on a voluntary basis at no cost. After hearing the spec. sheet, they said the NASA concept of teleoperator application is very much liked, and they are interested in exploring the possible mining applications of NASA technology--particularly the control panel. Some of BuMines current application areas that they specified for teleoperators are the following:

- Cutting
- Continuous mining
- Roof bolting machine

The teleoperators can be of great value during mining operations, as they prevent direct human contact with hazardous conditions. They requested detailed descriptions of the devices NASA has under development.

4. a. Hewlett-Packard Co. - Non-Destructive Evaluation (NDE)

After 3 attempts, reached Mr. Garry Garrettson who is the Director of the H-P Engineering and Physics Laboratory (415-857-2670). He said Hewlett-Packard is working with NDE, but only as a tool-not as a product. That is fine with us, because all we are interested in is how what they do compares with NASA's work, and whether or not they would be interested in NASA's accomplishments. After discussing some of our

specifications, he stopped and said he was not qualified to make a considered judgement on NASA's work. He, therefore, referred caller to Mr. Ed Karrer on X3354. Garry said that most of their work was in medical instrumentation and therefore might be more specialized than we would want. This should not influence us, because we aren't concerned with the actual application but more interested in the NDE equipment and techniques. Applications can vary all over the place, but the methods used are our chief concern in effecting technology transfer in NDE.

Gary Garrettson's remarks follow closely those offered by the other people caller talked with, and that is--they have a very positive attitude about NASA's R&D programs, and they would like to keep involved with whatever NASA is doing in the fields of interest to them. However, more work has to be done to get down to specific technologies before they will become active.

Later called Ed Karrer, but he left for about 2 weeks. Caller was referred to Teddy Kiang X4473.

Ted Kiang said he would like to review our spec sheets before he made any comments. It seems he wanted something in writing to show his superior, although he didn't say so. His address is:

Ted Kiang  
Hewlett-Packard Co.  
1651 Page Mill Rd.  
Palo Alto, CA. 94304

Overall, he felt that as far as NDE imaging NASA was average, but behind in other areas; however, he stressed that it all depends on the application and what NASA is aiming for.

b. Boeing Aerospace Company - Non-Destructive Evaluation (NDE)

Three persons at Boeing Aerospace Company were contacted to discuss NASA's high resolution ultrasound technology, using the spec. sheet we prepared. They are listed as follows: Leou Haggan, Chemical Laboratory (206) 237-1283 William May, Non-Destruction Testing (206) 237-2311 Steve Lariviere, Research & Development (206) 237-0537. We found that Boeing uses ultrasonic devices regularly for materials testing,

during both research and inspection activities. The Research Section buys the new ultrasonic devices for NDE, develops its applications, and performs testing. If the new device meets Boeing's requirements, they then develop procedures for actual use. They are currently using the S-80 reflectoscope for identifying a 364 flat bottom hole. This equipment operates at a maximum frequency of 10 megahertz. It categorizes cracks or faults on amplitude area relationships. The NASA technology, using up to 100 megahertz frequencies, is for microstructure inspection and to reveal or identify very small flaws (5 to 8 microns). At present Boeing does not require this capability, but they think they could have applications for it in the future. Boeing Aerospace personnel are very much interested in NASA's high resolution ultrasound technology, as well as techniques for making use of it. They requested that detailed descriptions of NASA's work and specifications be sent to them.

5. a. EPRI - Mega-ampere Switches

Two officials of significant stature at EPRI were contacted regarding NASA's development of mega-ampere switches. They were Dr. Narain Hingorani, head of the Electric Systems Division and an expert in HVDC transmission, and Ralph Ferraro, who is in charge of research in power electronics. EPRI has more than six research and development groups that are currently working on about 700 new technologies. All of their efforts are directed toward electric utility company applications.

EPRI objectives being concentrated upon at present concern very high voltage, solid state devices for electric power transmission systems on the order of 500,000 volts. Dr. Hingorani indicated that NASA's mega-ampere switch may not have application for the utility companies, but he was more optimistic about its application for lasers and cyclotrons. He would like to see a NASA spec. sheet on the switches.

Both of these electrical experts showed interest in cooperating with NASA researchers, and for utilizing NASA's electrical technology for commercial application whenever possible. Dr. Hingorani would very much desire to meet with NASA researchers in his field and discuss emerging technologies.

b. Baltimore Gas & Electric Co.- Mega-ampere Switches

BG&E was contacted regarding possible use of mega-ampere switches under development by NASA. Since the switches presently under development are only useful to turn on mega-ampere currents, as for lasers, BG&E has no application for them. They would be very interested in a similar switch to turn off (as a circuit breaker) mega-ampere currents. Such a device could save considerable money and space in BG&E's electric power applications.

6. Exxon Corp - Tribology

ECO didn't have a spec sheet ready, but called the Exxon corporate headquarters and was referred to their research center in Florham Park, N.J. After many conversations, ended up with N.V. Bangaru who is fairly knowledgeable with the tribology work at NASA and Exxon. He felt, as a general comment, NASA was doing excellent work and in some areas was on the cutting edge of technology. He would like to see a spec. sheet when developed, and he wants to keep informed. His telephone number is (201)-765-2825.

B. List of Companies Contacted

Baltimore Gas & Electric Company  
P.O. Box 1475  
Baltimore, Maryland 21203  
(301)- 234-5511

Union Carbide Corp.  
Old Ridgebury Road  
Danbury Conn. 06817  
(203)-794-2000

Unimation, Inc. (Westinghouse)  
Shelter Rock Lane  
Danbury, Conn. 06810  
(203)-744-1800

Teleoperator Systems, Inc.  
45 Knickerbocker Avenue  
Bohemia, Long Island, N.Y. 11716  
(516)-567-8787

Hewlett-Packard Co.  
1501 Page Mill Road  
Palo Alto, CA. 94304  
(415)-857-1501

EPRI (Electric Power Research Institute)  
P.O. Box 10412  
Palo Alto, CA. 94303  
(415)- 855-2000

Exxon Corp.  
1251 Ave. of the Americas  
N.Y., N.Y. 10020  
(212)-398-3093

Exxon Research Center  
Florham Park, N.J. 07932  
(201)-765-2825

The Boeing Company  
Washington, D.C. Office  
1700 N. Moore Street  
Rosslyn, VA 22209  
(703)-558-9600

Boeing Aerospace Company  
P.O. Box 3999  
Seattle, WA. 98124  
(206) 655-1131